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SIX THOUSAND YEARS OF HISTORY

BY

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TEN VOLUMES

VOL. X

ACHIEVEMENTS OF THE XIX CENTURY

E. R. DuMONT, PUBLISHER

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REMARKABLE ACHIEVEMENTS OF THE NINETEENTH CENTURY

A CENTURY OF ACHIEVEMENT

In the one hundred years now drawing to a close the world has made a greater advance in science and the arts than in all the preceding ages. The human mind reels when it tries to grasp the stupendous achievements of the Nineteenth Century, in every branch of discovery and invention. Because of their love of pure knowledge, men of gigantic intellect have sought out the mighty secrets of the universe and have raised to the sky a temple to science on ground upon which stood, a century ago, only scattered and isolated stones. Close behind the worshipers of knowledge have followed the magicians of to-day; chemists, engineers and electricians. At their command the spirits of air, water, earth and fire have been made to do man's every bidding. They propel his steamships, railway cars and mighty engines; they make his garments; they build his houses; they illuminate his cities; they harvest his crops. For him they make ice in the tropics or grow oranges amid snow. For him they fan a heated atmosphere into cooling breezes or banish icy winds. They flash his news around the globe; they carry the sound of his voice for thousands of miles, or preserve it after he is dead. Verily the fairies and genii of old did not so much for Solomon in all his glory.

During the Nineteenth Century, man has made a messenger boy of the lightning, and harnessed vapor to his

chariot wheels, and all this he regards as a matter of course. Men and women alive to-day can remember the introduction of the first steamboat and the first locomotive. They can recall their delight at the first daguerreotype. Yet their grandchildren from their cradles have been used to electric street cars, ocean greyhounds and kodaks.

We are benefited by thousands of practical applications of the discoveries of wise and patient men, but do not pause to consider the wonder of it all, and how new a power science is in the world.

It is well-nigh impossible to realize the state of science one hundred years ago. All was inchoate. Great truths, germs of much that has been developed since, had been discovered and were startling the world by their novelty and their simplicity. But they stood apart, nor did man dream of science as a single rounded and connected whole. When we regard the astonishing structure that has been built since then, the materials for which have been hewn in so many forests and quarried from so many mines, it seems incredible that a single century can have witnessed so many brilliant achievements.

Astronomy, a hundred years ago, stood foremost of the sciences, most ancient, as most advanced, of them all. Job mentions Orion and the Pleiades, and the Wise Men of the East were reading the heavens when the Star of Bethlehem blazed upon their sight. The Phœnicians steered their ships by the polestar, and followed the planets in their courses. Nevertheless, astrologers learned little that was new, as the centuries passed. Complex lenses were unknown, and with the exception of the planet Uranus, discovered by Herschel in 1781, and the moons of Jupiter and Saturn, no additions had been made to the solar system, since the days of the Chaldeans. As for other solar systems they were scarcely dreamed of. Aldebaran, "the

fixed star, the star which changeth not;" Sirius, and the rest, were but lights in the sky which exercised a weird and mysterious influence over the destinies of men, and were studied by sages to that end. The beginning of the Nineteenth Century, 1801, saw the discovery of Ceres, the first of the asteroids; five more were found between that date and 1847, and since then more than four hundred minor planets, belonging to the same system, have been catalogued. The discovery of the planet Neptune, in 1846, was the result of a triumph of mathematical reasoning which confirmed the Newtonian theory. As recently as 1836, Auguste Comte had maintained that the measurement of the distances of the stars was an impossibility; the Newtonian theory incapable of proof; and that the chemical composition of the fixed stars must forever remain a secret to mankind. Three years after this dictum, Bessel had measured the distance of the star sixty-one Cygni, and Newton's theory had been abundantly proved. Now the invention of the spectroscope, combined with the discovery of spectrum analysis, enables us even to study stellar chemistry.

One hundred years ago we knew so little about the chemistry of our own world that oxygen was a brand new discovery. Since then, what vast advances have been made in chemistry alone! Its range is almost boundless. Man has penetrated to the innermost secrets of matter, and has applied his knowledge in a thousand ways to the arts. It is not too much to expect that before long he will possess the secret sought by the philosophers of old and be able to transmute baser substances into gold.

Marvelous, indeed, is the progress which has been made in the physical sciences during the Nineteenth Century. Three achievements alone are sufficient to crown the age with glory. These are the doctrines of the mo-

lecular constitution of matter, the determination of the mechanical equivalent of heat, leading to the theory of the conservation of energy; and the doctrine of evolution, as divined by Darwin.

The principles of philosophy have been brought to bear on the complex phenomena of the atmosphere, and meteorology has grown to be more and more nearly an exact science. Not only are cyclones, hurricanes, tornadoes, hail-storms and blizzards foretold, but the weather bureaus predict the slightest shower or the lightest changes in temperature.

One discovery leads to another and science has been applied to a myriad of practical uses. One hundred years ago man possessed the germ of electricity which has developed so wondrously during the century. It was regarded as little more than a costly toy. Now we have the telegraph, the ocean cable, the electric railway, the telephone, the phonograph, the gramophone, the telautograph, the kinetoscope and the Roentgen rays. Only to mention these things is to use words never heard a hundred years ago, though so familiar now. To-day electricity rings bells, opens and locks doors, lights and heats dwellings, drives fans, works sewing machines, does cooking, moves elevators. It is even used to illuminate the *fin de siecle* Christmas tree.

Steam is another giant which was a puny infant in 1800. Robert Fulton, the first man to make a success of a steamboat, launched the Clermont on August 4, 1807. It took thirty-two hours to make the trip from New York to Albany. The magnificent ocean greyhound of to-day travels from New York to Liverpool in six days. Stephenson's first locomotive, built in 1814, traveled only six miles an hour. The first public steam railway was not operated until 1825. At that time there was not a mile of

railroad in the whole United States. To-day there are 445,064 miles of railroad in the world, the mileage of the United States being nearly half that of the world.

The steam engine dates from the last century, but many and various have been the improvements of and developments from the older machines until, to-day, to take a single example from thousands, the modern printing press prints, pastes, folds and counts 90,000 four-page or 24,000 sixteen-page papers an hour. In the art of printing the typesetting machine is a marvel. By its use melted metal is run into type set up and ready for the column before leaving the machine.

The cotton and woolen industries have grown enormously during the Nineteenth Century, owing to the marvelous application of machinery and steam to all branches of the trades. The cotton gin and the spinning jenny were inventions of a previous age, but to our own time belong multitudinous developments of these humble beginnings as well as innumerable other aids to the spinners' and weavers' arts.

Ice-making and refrigerating methods and machinery and coal-handling devices are wonders of recent invention, as are numerous and infinitely varied methods of transportation. Not only have we the steamship and the railway but many kinds of electric cars, horseless carriages, electric and gasoline, besides the bicycle, whose use has become so general. The air is navigated by balloons and flying machines, which, though still somewhat imperfect, are wonders of inventive genius.

The first effective sewing machine was not made until 1845. Since then how rapidly have sewing machines been improved and adapted to every variety of work! There are now special machines for making button-holes and sewing on buttons, for embroidery, for carpet sewing, for

leather work and for making and repairing shoes. Another remarkable mechanical invention of the age is the typewriter. Many were the difficulties to be overcome in perfecting this complex machine, yet, so great are the resources and ingenuity of modern machinists that the problems have been solved in many different ways.

At the dawn of the century there was not only no electric light, but there were few lamps and little gas. As for matches, their place was filled by tinder, flint, and steel. It is well-nigh impossible to realize the darkness of the time. The methods of illumination at the end of the Eighteenth Century were almost identical with those which had been used throughout the whole period of history. The usual lamp of one hundred years ago was constructed on the simple principle of those of ancient Greece and Rome, and consisted of a clay cup containing a little melted animal fat and a fibrous wick, but torches and tallow dips were the general mode of illumination even among the well-to-do. Argand burners were introduced at the very end of the Eighteenth Century, but they were not sufficiently improved or cheapened to come into use before 1830. Gas was first used for out-door illumination in 1813, when Westminster Bridge, London, was lighted by it. Since then, its use has spread all over the world. A great step in human progress was achieved when man, who for ages had revered or feared gas as a demon, made it his servant and tamed it to his uses. This great feat of illumination was not enough for this wonderful century, surpassing though it did the accumulated efforts of ages. Since Franklin caught the lightning with a kite and a key, electricity, the Nineteenth Century miracle, has rapidly superceded gas, making bright the darkness. Its searchlight penetrates the deepest caverns, rendering the miner's lantern a thing of the past; it explores

the depths of the ocean, nay, more, science has taught it to serve the surgeon, for it illumines the opaque and exposes the interior mechanism of man without the aid of a knife.

How beneficent, generous, helpful is the science of to-day! The practice of surgery and medicine have undergone magical changes through her tuition. The combined uses of anæsthetics and antiseptics have almost revolutionized surgery, robbing the knife of its terrors and rendering possible a multitude of tedious and difficult life-saving operations. Yet not until 1847 did the era of anæsthetics begin, enabling the surgeon to eliminate the agony of his patient, and to perform his boldest feats with quiet confidence and leisure.

In popular estimation, perhaps justly so, the establishment of the doctrine of evolution is considered the greatest scientific achievement of the Nineteenth Century. Through it the mental horizon has been immeasurably enlarged. Darwin's name is inseparably connected with evolution, but evolution is greater than Darwinism as the whole is always greater than a part. Under the laws of evolution have been brought the stellar universe and solar and planetary systems no less than the species of plant and animal creation. Astronomers, geologists, and biologists have constructed and established, bit by bit, a beautiful theory of the development of all things. Modern geology is almost entirely a growth of the Nineteenth Century while biology, a hundred years ago, was studied only under the misleading name of "natural history." When the century was young, there were educated men who gravely maintained that fossils were "sports of nature," created already dead and petrified. As late as 1857, Gosse, the English naturalist, held that all the evidences of convulsive changes and long epochs in strata, rocks, minerals

and fossils were simply "appearances," all created at the same time. As advances were made in physics and chemistry, men began to comprehend the secrets of the formation of the earth. While astronomy steadily advanced toward the proof that the physical forces at work in the infinitude of space are the same as those at work on earth, geology, in carrying us back to immeasurably remote periods of time, taught that the same laws have been in operation from the beginning.

Many have been the practical applications of the century's discoveries in the field of biology and enormous their influence on the practice of medicine. The discoveries of the cell theory and the science of embryology, the germ theory of disease and the nature and function of the white blood corpuscles or leucocytes have all been turned to account. Men such as Pasteur and Koch have devised ways to render powerless the most dreaded zymotic diseases and put to flight the deadly bacilli.

At the dawn of the century psychology groped bewildered in the darkness of abstract metaphysics. The sciences of man, language, societies and of religion were unborn. Questions as to the antiquity of man had not arisen. The figures of speech of Moses were interpreted literally, and the universe was believed to have been created exactly as it is now, only six thousand years ago. Now we know that its origin goes back through aeons of time. Anthropology, philology, sociology and the science of religions, children of the Nineteenth Century though they be, have attained full stature during the one hundred years through the triumph of the comparative method of study. The history of the growth of articulate speech and of all language has been sought and found, as has the history of the development and growth of most of the customs and institutions of man. Not only have the sto-

ries of the ancient civilizations on the banks of the Tigris, the Euphrates and the Nile been traced out for us in bewildering detail, but we have been made conversant with the minutest particulars of the life of pre-historic man. With pick and spade the devotees of anthropology and archæology have laid bare the secrets of old Mother Earth.

While one army of workers has been examining the history of the past ages, others have been solving the problems of the present. A wonderful advance has been made in institutions of every kind during this most marvelous century. Slavery has been abolished among civilized nations and the slave traffic driven from the high seas; popular education is the rule in enlightened countries, so that every child is now taught to read, write and cipher; higher education for women is an established fact and free schools and colleges place thorough education within the reach of every young man and woman who is willing to take the trouble to obtain it. Reform has changed government prisons from dens of fever and corruption into sanitary places of restraint. Comfortable hospitals under the management of expert physicians and capable nurses open their doors to the sick. Insanity is dealt with as a disease, and not as a crime; the deaf hear; the dumb speak, and the blind are well-nigh as efficient as those who see. Free libraries in every town of any importance yield the treasures of the great minds of the ages to all. The price of books is so low that every working man may possess his own library; lithography and the engraver's art illustrate ten cent magazines with pictures which fifty years ago were beyond the reach of all save the rich; while he who wishes to present his likeness to a friend has the sun for a painter and is no longer obliged to pay hundreds of dollars for a portrait. The news of the world may be had for a penny within a few hours of its

happening, and for a few cents private letters are carried by steam to the antipodes.

Not least among the achievements of the Nineteenth Century is what has been done for the farmer, and through him for the hungry world which he feeds. A hundred years ago wooden plows were in use not dissimilar from the one driven by Elisha of old. At that time there were no reaping machines. In the heat of midsummer, without protection from the broiling sun, the working men of the world gathered the harvest, sickles in hand, while the women crept after them and kneeling bound the sheaves. So trying was the work that double wages were paid for harvesting and farmers engaged their men months ahead of time. A little more than fifty years of American invention has changed all this. Seedtime and harvest are no longer dreaded, for wonderful machinery has come to man's aid. He does his plowing, riding comfortably over the fields, sometimes drawn by horses, sometimes propelled by steam; and the plowing and harvesting of the great wheat fields of the West are less laborious than was the cultivation of a few acres in former times. Wheaten bread is no longer a luxury for the few, and the five-cent loaf, kneaded and baked by steam, is sufficient to breakfast a family. American farm machinery is used all over the world. To such an extent has the industry of producing it grown that 150,000 self-binding harvesters, each doing the work of twenty men, are made annually.

Among the great engineering feats of the age are marvelous bridges built of iron and steel suspended or arched over chasms or waters long thought to be unspanable. Accounts of the mechanical skill of the Egyptians have come down to us through the ages. Vestiges of their engineering works have been found buried in the sands of

centuries, proving that the mighty men of the Nile possessed secrets lost long ago and not re-discovered until the Nineteenth Century; but that which Pharaoh-Necho attempted and failed to do, long before the time of Christ, was accomplished when the Isthmus of Suez was cut through allowing ships to sail entirely around the continent of Africa. Innumerable other canals have been constructed by the ingenuity, skill and patience of the engineers of to-day, who have likewise built great tunnels, blasting their way through mountains, driving "shields" under rivers and forcing "needles" under city streets. The congested condition of the business districts of large cities has called forth a new style of architecture and lightly built edifices of steel, lift story after story skyward, rivaling the Tower of Babel. Many and various are the obstacles overcome in the erection of these big business buildings with cantilever and truss innovations, and a legion of necessary or ornamental appliances or appurtenances. Recently the growth of these office buildings has been checked by legislation in many cities, but sixteen or twenty story structures are by no means rare.

The engineer has brought his skill to bear on mining and mining machinery so that methods of drilling, boring, blasting, sinking shafts, exploring, excavating, and ore extracting have completely changed during the century. What used to be done by hand is now performed by the mighty giants, steam and electricity. Closely connected with the improvements in mining are the achievements of metallurgy, including the inventions of Bessemer and Siemens which have so vastly increased the possibility of the steel industry, not only cheapening steel, but conducing to many other wonderful results. Another achievement of the age is the invention, or discovery, of acetylene gas, which may do away with coal gas as an illuminant, and

there are processes by which that most useful metal of the future, aluminum, is obtained and cheapened. During the century there have been marvelous innovations in water wheels, producing great force, and the mighty Niagara has been harnessed and utilized for power purposes. Air has been compressed and liquified and great are its possibilities.

Not only have the gold fields of the Klondike, Australia and South Africa been discovered in this century, but most of the inexhaustible mineral resources of the Western Hemisphere have been found and made known to the world since 1800. It is difficult to imagine how mankind got along without the silver of Nevada and Colorado, the gold of California, and the coals and petroleum of Pennsylvania, West Virginia and New York, to say nothing of the wealth hidden in the mountains of Central and South America.

The exploration and development of unknown parts of the globe during the century has been phenomenally rapid and extensive. A large part of the history of America and of Australia has been the history of courageous, persistent and successful exploration, "wherein the track of the explorer, serving instantly for the trail of the pioneer, has broadened into the wagon road of invading immigrants." Light has been thrown on darkest Africa, through the unwearying effort of men, such men as Livingston, Du Chaillu and Stanley; land has been discovered and explored in the Antarctic region of snow and ice, and intrepid men have conducted with extraordinary patience, fortitude, and enterprise, one expedition after another in search of the North Pole. All this discovery and opening up of new worlds has played a vast part in the progress of man in commerce, science and civilization, and is to be

accounted one of the mightiest achievements of the century.

Not only in the arts of peace has man taken great forward strides. Methods of warfare have been completely revolutionized by recent improvements in armor and guns, by fearful projectiles, by sub-marine boats and their deadly explosives, and by smokeless powder. Arbitration frequently prevents war, thereby saving thousands of lives and prophesying a time when battles shall be no more. Human life is more highly valued now-a-days. Capital punishment in civilized countries is administered for only the gravest offenses. There have been wonderful improvements in lighthouses and life-saving ocean and sea devices, and the Red Cross physicians and nurses and the hospital tent or ship, follow army and navy.

Wonderful has been the part that the United States has taken in the multitude of astonishing achievements of the Nineteenth Century—always abreast of the times, often leading. Yet in 1800 the Republic was less than twenty-five years old, so that her greatness and eminence of itself is a growth of the century. In 1800 a country with only 5,308,483 inhabitants, hugging the seacoast, the United States has grown to an immense area and to a population of nearly 75,000,000. Struggling during the period with grave domestic problems, many of them entirely new, learning, growing, building, organizing; to-day the United States leads the world in wealth, mining, agriculture, fisheries, forestry, transportation, education and almost every field of endeavor. Her own development chiefly an achievement of the century, she has led in making the Nineteenth Century the age of greatest achievement.

TRANSPORTATION

Many are the methods of transportation which have been in use throughout the centuries, but the customs of civilized man to-day differ from those of a hundred years ago more than those of 1800 differed from those of the first year of the Christian era. Travel in some parts of the world is still as slow and as torturous as it was in the days of old. The jolting of the dilligencies of Southern Europe and of the bullock wagons of Africa are provocative of extreme discomfort, and although sledge-riding over the frozen steppes of Siberia may be the poetry of motion, it must be seriously alarming to hear wolves howling on one's track. When an African King journeys riding pick-a-back, or a Chinese lady of rank takes an airing in a dark chair, their methods of travel are far from up to date; but they are not fit representatives of the age. Nineteenth Century man has tamed steam and electricity, marvelous steeds, indeed. Yet when this wonderful Century dawned on the world our ancestors were able to travel no faster than were Abraham and Sarah when the world was young. The ass for patience, the camel for endurance, and the horse for speed were the best the world afforded for travel for thousands of years.

At the beginning of the Century land journeys were made by stage coach and the sedan chair still carried my lord and lady about town, although there were a good many new-fangled vehicles, such as landaus, landaulets and barouches, with clumsy iron and wood cross beds instead of springs. During the first quarter of the Cen-

tury carriage building made great progress, and cabs and curricles, gigs and whiskies rode down the now antiquated sedan chair.

At this time the common people walked or, in the country, rode in the carrier's cart; the usual mode of traveling was on horseback, the husband astride the saddle and his wife behind on a pillion with her arms tight around his waist to keep from falling. The pack-horse, clumsy wagons, and the canal boat were generally used for the transportation of merchandise, while people, in the main, performed their long journeys by stage coach or the carrier's cart.

In the year 1804 Obadiah Elliot, a coach-maker, patented a plan for hanging vehicles upon elliptical springs, thus dispensing with the heavy iron and wood beds that had been invariably used in four wheel carriages up to that time. In 1814 there were 69,200 carriages in Great Britain. Dogcarts and tandem-carts had their origin in the beginning of the Century, as did a daring vehicle called the "suicide," which carried to an extreme the passion for lofty perches from which to drive.

In 1829 the first public omnibus appeared in London. Victorias became popular in 1869. The buggy is an American invention of the first part of the Century. It gained much admiration from English coach-makers, who were surprised at the extreme lightness, ease and durability with which it could travel over rough roads.

The coaches, landaus, broughams, spiders, runabouts, game carts and dogcarts of to-day show to what extent the carriage manufacturer has developed his art. They are models of grace and beauty, and infinite in their variety. Wagons have undergone as many improvements as carriages during the Century. There are appropriate wagons for every use in city or country. The use of

steam and machinery in their manufacture has cheapened the price of vehicles and enabled great factories to build them by thousands, but the carriage of the millionaire or monarch of to-day may cost two or three thousand dollars.

This remarkable prophecy was made in 1781 in a poem published by Erasmus Darwin:

> "Soon shall thy arm unconquered steam afar,
> Drag the slow barge or drive the rapid car."

As early as 1787 Oliver Evans, of Philadelphia, is said to have invented a steam carriage, or locomotive, a model of which was sent to England. America can thus claim to have built the first locomotive, although the honor of having done so is usually ascribed to Great Britain. On Christmas Eve, 1801, according to some authorities, Richard Trevithick made the first trial of his locomotive at Cambourne, carrying the first passengers to travel by steam. There is confusion, however, as to the dates of the trial trips of Trevithick's engine, although it was certainly exhibited both in London and Wales prior to 1809, attracting much attention on the Merthyr Tydvil line. To quote a newspaper of the time, it "traveled with ease at the rate of five miles an hour," and conveyed "along the tramroad ten tons long weight of bar iron from Penydarren iron works to the place where it joins the Glarmorganshire canal, upwards of nine miles distant; and it is necessary to observe that the weight of the load was soon increased by about seventy persons riding on the trams, who, drawn thither (as well as many hundreds of others) by curiosity, were eager to ride." Trevithick's locomotive was but little more than a model. It was full of imperfections and, being unable to make steam, could not travel fast or draw a heavy load. It remained for the Stephensons, father and son, to pro-

duce the modern locomotive. George Stephenson's first locomotive was made in 1814, and from that year the invention of the locomotives is generally said to date.

The first public steam railway in the world was formally opened in England, September 27, 1825. The Stockton and Darlington was thirty-eight miles in length. The line was laid with both malleable and cast iron rails, and cost 250,000 pounds. Its opening was attended with great curiosity and excitement. There was to be a competition between various kinds of motive power horses, stationary engines and a locomotive being tried. The train consisted of six loaded wagons, a passenger carriage, twenty-one trucks fitted with seats and six wagons filled with coal. George Stephenson drove the locomotive. "The signal being given," says a writer of the time, "the engine started off with this immense train of carriages, and such was its velocity that in some parts the speed was frequently twelve miles an hour, and the number of passengers was counted to be 450, which, together with the coals, merchandise, and carriages, would amount to near ninety tons. The engine, with its load, arrived at Darlington, travelling the last eight and three-quarter miles in sixty-five minutes. The six wagons loaded with coals, intended for Darlington, were then left behind, and obtaining a fresh supply of water, and arranging the procession to accommodate a band of music, and numerous passengers from Darlington, the engine set off again and arrived at Stockton in three hours and seven minutes, including stoppages, the distance being nearly twelve miles." The passenger coaches, with their rough, uncomfortable seats, were in great contrast to the plainest passenger cars of to-day, but people crowded the "waggons" with feelings of mingled curiosity, delight, suspense and fear, and there were six hun-

dred persons on the train when it returned to Darlington. There was one coach, however, which was the precursor of the luxurious drawing-room car of to-day. This was the "Experiment," an invention of George Stephenson's, built like an omnibus, with the door at one end, seats down each side and a deal table in the aisle. This well appointed coach was a success, and was used for some time afterward on the Stockton and Darlington Railway line, being drawn by horses.

In 1829 the Stephensons invented the steam blast, which, continually feeding the flame with a fresh supply of oxygen, enabled the "Rocket," their prize engine, to make steam enough to draw ten passenger cars, at the rate of ten miles an hour.

In 1830 the Liverpool and Manchester Railway was opened in spite of bitter opposition from landowners and canal companies, who sought in every way to prevent the building of the road. The surveyor and his assistants were attacked with guns and pitchforks and sticks.

"I was threatened to be ducked in the pond if I proceeded," says the engineer, "and, of course, we had a great deal of the survey to take by stealth at the time when the people were at dinner. We could not get it done at night and guns were discharged over the ground to prevent us."

The writers of the day denounced the railway in magazines and newspapers. Pamphlets were written against it, and it was even opposed in Parliament. Said a quarterly reviewer of the time, commenting on a proposed line to Woolwich, which was to go at twice the speed of stage coaches:

"The gross exaggeration of the powers of the locomotive steam engine * * * may delude for a time, but must end in the mortification of those concerned. We

would as soon expect the people of Woolwich to suffer themselves to be fired off from one of Congreve's rockets as to trust themselves to the mercy of such a machine going at such a rate."

It was declared that poisoned air from the locomotives would kill birds and render the preservation of foxes impossible, that hens would stop laying and cows cease grazing. The people were told that should the use of railways become general, there would no longer be any use for horses, that the species would grow extinct, and oats and hay become unsalable. But George Stephenson was strong enough to withstand all attacks. It was while he was undergoing examination from a Parliamentary committee that the familiar anecdote about the relative strength of the locomotive and the cow originated.

"But suppose, now, Mr. Stephenson, one of these engines, going along a railroad at the rate of nine or ten miles an hour, should encounter a cow; would not that be bad, think you?"

"Yes," replied the Scotch engineer, with a smile, "varra bad—for the coo."

Even after the building of the railway the directors hesitated about employing steam locomotives; but after the triumph of the "Rocket," in 1829, the power to be used for tractive purposes was finally settled, and the Liverpool and Manchester Railway became a success beyond the wildest dreams of its promoters. Many other lines were built, and the British people soon became accustomed to railway traveling. Very odd were the clumsy cars of those times. Most of them were open at the sides and protected only by rude awnings. Some of them contained benches, but in others it was necessary to sit on the floor. The first-class and mail train was en-

tirely covered in, and was tolerably well seated, but the most comfortable way of traveling was in one's own family coach, hoisted on a truck attached to the rear end of a train. This method of journeying became very fashionable with aristocratic folk.

The Stephenson locomotives, having but little side play to their wheels, were unable to go around sharp curves. Lines were, accordingly, made as straight as possible, and vast sums of money were spent in making easy grades. Deep cuts, costly tunnels, and bridges were necessary, and all lines in England were made with easy grades and slight curves.

Belgium is credited with being the first country on the European Continent to have a railroad. In conformity with a government decree, issued in July, 1834, Pierre Simin prepared plans for railway communication throughout the kingdom, and the Brussels and Mechlin Railway was opened for traffic on May 6, 1837. Railroads for general traffic were introduced in France in 1839, nearly ten years after the opening of the Manchester and Liverpool line.

While the period between 1825 and 1830 was pregnant with railway movements, it can scarcely be said that any railway was successfully operated in the Americas before 1830, when the Baltimore and Ohio Railroad opened its first section of fifteen miles from Baltimore to Ellicotts Mills. The first genuine locomotive in use in the United States was the "Stourbridge Lion," which made its trial trip several months before the opening of the Baltimore and Ohio road, on a railway connecting the coal mines of northeastern Pennsylvania with the Delaware and Hudson Canal. From 1830 to 1835 many lines were projected, and at the end of 1835 there were over a thousand miles of railway in use in the United States.

In 1831 the Baltimore and Ohio Railroad offered a premium of $4,000 "for the most approved engine which shall be delivered for trial upon the road on or before the first of June, 1831; and $3,500 for the engine which shall be adjudged the next best." The first prize was won by the "York," built at York, Pennsylvania, after plans drawn by Pheneas Davis, a watch- and clock-maker.

The celebrated locomotive "John Bull" was built by George and Robert Stephenson and Company, and was imported from England in 1831. This engine was exhibited by the Pennsylvania Railroad Company at the Centennial Exhibition at Philadelphia in 1876, and at the Columbian Exposition at Chicago in 1893.

Many locomotives were imported from England during the early days of the American railroad, serving, doubtless, at first, as models for American engine builders, but owing to the different conditions in the United States the American locomotive soon acquired a distinct individuality. Discarding precedent, our engineers invented and modified whenever they saw fit, and Yankee ingenuity made so many improvements that to-day American locomotives are acknowledged superior to all others, and are exported to every country which the railway has penetrated.

Necessity was the mother of invention; the money which Great Britain lavished on deep cuts and expensive tunnels was not forthcoming in the young republic, so the engineers of the United States put their wits to work and devised flexible locomotives which will round any curve, and ascend steep grades without difficulty. The chief and most important of these inventions is the swivel truck, which, placed under the front of the car, enables the driver to make a sharp turn with perfect safety, thus avoiding both the Scylla of a tunnel and the Charybdis

of a long detour, and saving millions of dollars in railroad building. Prior to its invention, it was supposed necessary that the track must be built in a bee-line, and the serpentine track which climbs mountains, and rounds hills, was deemed impossible.

As was done for the railroad of the Czar, which he commanded should run in a straight line, the engineers bored through mountains and filled in chasms regardless of expense. By means of the equalizing lever, another great invention, the weight of the engine is always borne by three out of four or more driving wheels. This prevents the locomotive from running off the rails, even when the track is a rough one, and the roadbed is uncompleted. Of late years swiveling trucks have been applied to cars as well as to engines, so that the modern train of a score of cars follows the locomotive with exactness and safety, and hugs the side of a mountain, where the track is laid actually on a shelf hewn in the rock, with utter disregard of the law of centrifugal force. During a period of less than seventy years, our railways have grown from small beginnings to rank among the wonders of the world, and the improvement in their equipment has kept pace with their rapid growth.

Peter Cooper's locomotive, built in 1830, had great difficulty in exceeding the speed of a good horse; the locomotive of to-day, which pulls the limited express, makes sixty miles an hour as a regular thing, and can increase it to seventy upon occasion.

The provisions of all sorts made for the comfort and safety of the passengers render travel a luxury, and the advertising illustration of a modern railway company, which depicts a party of travelers, descending from a Pullman car, freshly garnished and trim, guiltless of the dust, and free from the fatigue, of the journey, is scarcely

exaggerated. Passengers are carried, literally, from one point to another "on flowery beds of ease," and trips of a thousand miles are reckoned as pleasure excursions. The old iron track with its dangerous flat rail has given place to Bessemer rails, which nothing but time or fire can loosen from their place. The antiquated method of signaling by the frantic waving of flags has been superseded by electricity, which displays the signals high in the air, where "he that runs may read." Double and quadruple tracks, so that no two trains on crowded roads run in opposite directions, do away with all danger of collision, and the wobbly truck on which the rich man of a past generation was conveyed in his own coach, from point to point, is replaced by the drawing-room vestibuled car of to-day, "with kitchen, chambers, dining-room and parlor, all complete." Some of the trains de luxe being provided not only with libraries, and writing-desks, but with type-writing machines and operators, all of which may be enjoyed, while the train runs as smoothly as a skater on ice, or a sled upon snow.

The railway mileage of the United States in 1830 was less than sixty miles, including tracks for all purposes; to-day it amounts to 182,746.63 miles, nearly half that of the world.

There are now in actual use 35,810 locomotives, 25,275 passenger cars, 8,133 bag and mail cars, and 1,229,335 freight cars. The number of passengers carried in 1897 was 504,106,525; the number of tons of freight transported, 97,842,569,150; the gross earnings of all the railroads in the United States combined aggregating $1,123,546,666, or over $3,000,000 per diem.

The remainder of the railways of the world are distributed through almost every corner of the globe; the enterprising Anglo-Saxon has introduced his chariot of

fire wherever he himself has penetrated. It is quite in opposition to the fitness of things to fancy the journey to Jericho as made by railway, but not only does the modern tourist go from Jerusalem to that ancient city of the Bible, in a steam-car, but there is also a railway which runs from Joppa to Jerusalem. This last, the Jaffa-Jerusalem Railway, was opened August 27, 1892, when the first train ran from the ancient seaport to the City of David. This road, fifty-three miles long, cost $2,000,000 to construct, and the price charged for a first-class ticket for the round trip is $4. The Hindoo railway system, as might be expected under British rule, is the most complete and best stocked of all the Asiatic railway systems. Japan comes in a good second, with American-built locomotives, Bessemer rails, and engineers who have learned their trade in the United States.

The street railway company is a recent institution, and has been in general use for comparatively only a few years. The first application of the railway track to short-distance passenger traffic was not made until 1831, when John Stephenson tried the experiment in New York. The track was of flat bars, spiked to timbers laid on stone, and the car, one only, resembled an omnibus, built in three sections, with thirty seats inside, and thirty on the roof, making sixty altogether. Horse-power propelled it, and its route was from Prince Street to the Harlem River, along the Bowery and Fourth Avenue. In 1852, the Second, Third, Sixth, and Eighth Avenue lines in New York were begun with cars much like those used nowadays. Boston had no street-cars until 1856, nor Philadelphia until a year later, in 1857. Horse-cars were introduced into Paris in 1858, but it was not until 1870 that a tramway was permitted in London, and even now they are not allowed in the center of the city. They multiplied

rapidly in the suburbs, however, and during the twelve years following, 671 miles of track for horse-cars were laid in Great Britain. To-day there are street-cars in operation in every country in Europe, and also in Africa, Asia, in Japan, India and Ceylon, Australia, New Zealand, and in various parts of South America, as well as Manila, and in Honolulu.

It was not until 1873 that cable-cars were introduced. Prior to that date all street-cars were drawn by horses. The first cable-car was used in San Francisco in 1873. The experiment was abundantly ridiculed, as has been many another successful invention, and the steam-car among them, only half a Century before.

The new departure proved a triumphant success, and street-railways became possible on the steep hills which had been insurmountable to horse-cars—another instance of the manner in which American inventors always rise to the emergency.

The first city to follow suit was Chicago, in 1881, and in 1883 Philadelphia ran her first cable-cars on Market Street. The franchise in both cities belonged to the same company, and it has made its owners multi-millionaires. New York fought their introduction fiercely, and did not yield until 1886, while there were no cables in Baltimore until 1893. London built its first cable road in 1884, and New Zealand preceded the mother-country by a year, in the uses of the new means of locomotion.

The trolley-car is a yet more recent innovation. As early as 1835, Thomas Davenport, of Brandon, Vermont, constructed an electric car, operated on a circular track, but he made no more than the model. In 1851 an electric locomotive, which attained a speed of 19 miles an hour, was tested on the Baltimore and Washington Railway, but the first electric railway to prove a financial success

was not built until 1881, when Siemiens and Halaske operated one in Germany. There was intense prejudice against the electric railway in the United States on account of the danger from live wires, a prejudice fully justified by the number of casualties which occurred during the first years of their use; but experience taught the safe management of the deadly fluid, and the trolley-car is now among the institutions in every town in the country. Horse-cars every year grow rarer, and the trolley is fast superseding the cable in the large cities. Elevated and underground railways are successfully operated in various European and American cities, wherever the problem of rapid transit through crowded streets renders surface tramways dangerous, not to say deadly, and electricity is becoming more and more general as their motive power.

As yet the great expense of substituting electricity for steam upon railroads has prevented its adaption to locomotives, but experiments have proved that a greater rate of speed is possible to both locomotives and steamships, by the use of electricity, than by that of steam, and that it is possible to obtain more electric power than steam power from the same amount of coal, while the waterfalls have been utilized so that in all probability electricity will be the motive power of the future. Still there is talk of a coming rival. Compressed air is another propeller successfully used for locomotives and engines. It is kept both in storage batteries and in tanks, and is much liked not only for its results as to speed, but on the grounds of economy, cleanliness, and safety.

It is said that the progenitor of the modern bicycle existed nearly two hundred years ago, for there is a figure of a two-wheeled hobby-horse, on a stained-glass window in Stoke-Pogis Church, Bucks County, England,

which window is 190 years old. Back in the beginning of the last Century, a strange device, called a hobby-horse, was introduced among novelties in vehicles. It was constructed with two wheels, joined tandem, by a frame of wood. The saddle for the rider was on this midway between the wheels. He, the rider, propelled the machine by means of long strides taken on the ground. Its motion was restricted to a straight line, and locomotion therewith was tiresome, and chiefly valuable for purposes of exercise.

Still the earliest velocipede worthy of the name was a clumsy contrivance, which was patented in 1816, in France, by one Baron von Drais, under the name of the pedestrian curricle. Two years later, an improved form of the "Draismene" was introduced into England, but being impractical and clumsy, it met with ridicule rather than success. When it crossed the Atlantic in 1819, it met with more success in the United States, and was quite the fashion for a little while, although the fancy for it soon died out. The next step in the evolution of the bicycle was not made until 1846, when a Scotchman named Dalzell invented a wooden safety bicycle, which, though a great improvement upon anything which had preceded it, was not sufficiently practical to be adopted to any extent. Velocipedes and tricycles of various patterns were patented in the United States, and were popular, chiefly for children and cripples. In 1869 M. Michaux, of Paris, invented a bicycle in which the front, or driving, wheel was very much larger than the rear wheel. Just about this time velocipede-riding was the rage in the United States. Rinks and riding-schools were opened in all the larger cities, and the fashion was almost as great as that for roller-skating a few years later. The fast youth of the period called the popular velocipede of the day, the

"bone-shaker" and it required some dexterity to manage it. This had wheels of nearly equal size, the pedals being applied directly to the front wheels. The rider's position between the two front wheels was an uncomfortable one, and the clumsy machine well deserved its name.

The first bicycle of iron and steel was invented by another Frenchman, M. Mayer, also of Paris. Later on the principle of crank action, as applied to revolving wheels, becoming understood, the era of the bicycle was fairly inaugurated. Rubber tires and strong brakes rendered the motion easy, and one by one clever mechanicians discovered improvements which have rapidly made the machine the beneficent institution which it is to-day—an actual comfort to thousands of men and women, who find in it a pleasant means of exercise and recreation. The high wheel of fifteen years ago was not ungraceful when ridden by an expert, but it was dangerous at best, and was wholly unfit for the use of women. So the low safety wheel made its appearance in 1883. The girl of the period soon found that she could ride her brother's wheel as well as he could, and the obliging American manufacturer forthwith made one specially adapted to her use, to be rewarded by the sale of as many as he could make. No one now doubts that the bicycle has come to stay. Its use has spread all over the world, and the prejudice against it which at first existed has almost disappeared. Persons of both sexes, from the small boy and girl to the gray-haired grandfather and grandmother, in all stations of life, ride it for pleasure and for health, and it is every day more and more used for business purposes.

The motor-cycle, or automobile, is yet another astonishing product of the Nineteenth Century. Although its germ was evolved as long ago as 1769, when a French army surgeon rigged up a gun-carriage and a big copper

boiler in such wise that it was driven by its own power. In 1784 a road-engine was invented by a Cornishman, and in 1786 William Wymington designed a carriage which was propelled by a locomotive behind. The Orleton Amphibolus was a curiosity in Philadelphia in 1804. This was an odd sort of vehicle, mounted on wheels, and run by its own steam engine, which was part of the structure. When finished it was driven successfully to the Delaware River, where it was used for dredging the Philadelphia docks. Inventive mechanics produced more or less successful road-engines, until the appearance and perfection of the locomotive brought railways into general use, and the need for them no longer seemed apparent.

During the last decade the development of electricity and the perfection of the steam-engine has set inventors to devising new uses for them, especially for applications of that wonderful invention, the storage battery. France, where the roads belong to the government and are kept as carefully as the walks and drives in a city park, has led in the attempt to produce a carriage which should be rapidly and economically propelled by a small storage battery. The undertaking has met with fair success, and the moto-carriage is too common a sight on the Parisian boulevards to attract much attention from other than tourists, while their use in American cities is rapidly increasing. Bicycles are frequently run in the same manner, and the use of the automobile is constantly becoming more general. There is serious talk of making the omnibusses automobilic, and some of the electric trams are run by means of storage batteries without wires overhead.

In 1894 an automobile race was held between Paris and Rouen, and this was followed in 1895 by great races on the highway from Paris to Bordeaux. At the Paris

Automobile Exhibition, which was held in 1898, more than 1,100 automobiles were on exhibition. Each one of the number was submitted to a practical test before being admitted to the show. Among them were horseless vehicles, of all sorts, including broughams, phaetons, victorias, buggies, omnibuses, delivery-vans, and wagons of various kinds; tricycles and bicycles; mail-coaches and excursion wagons, and odd-looking square vehicles, which are merely square engines with two seats at the back like a carriage, with the front cut off. They were propelled by gas, petroleum, and naphtha; by steam and by electricity. For general use, the petroleum-gas engine is considered by French experts to be the best and most practical. This can be kept running, at a fair rate of speed, for three hundred miles with a few gallons of gasoline. Notwithstanding the fact that the first motor-carriage was built in England, France has made the idea her own, and far distanced Great Britain in its development. The English law has contributed greatly to this result. Until recently, the laws of the United Kingdom required that every motor vehicle on the Queen's highway must be preceded by a man, bearing a red flag, and that it must not travel at a greater rate of speed than two miles an hour. This antiquated law has lately been repealed, and much interest was shown by the British public in the recent exposition of motor-carriages held at the Imperial Institute in London. In Germany the motor-carriage has reached a high degree of perfection. Much interest is felt in the automobile in the United States, although the condition of most of our public roads is such as to interfere greatly with its use to any extent.

In Ceylon several motor-carriages have been purchased to carry the royal mails. The motocycle is attracting much attention in India, where it is predicted

that it will eventually supersede the use of the elephant, the horse, and the camel. The great elephant catcher, Stephenson, is said to be the pioneer in the use of motor-carriages in India. It is reported that he makes use of a steam motor on his hunts, and prefers it to any other means of locomotion.

The steamship is a child of the Century, and a wonderful change has been wrought since the day, less than a hundred years ago, when the American clipper ship was the queen of the seas, a greater change than had been brought about from the days of Noah's ark down to the beginning of the Century. The changes have been due first to the application of steam as a motive power to vessels and then to a change of construction from wood to iron and steel. The application of steam to ships is, however, of earlier creation than the railroad. As with so many other things the germ of the idea is to be found in the discoveries of a previous Century. There are many claimants to the honor, and although there is strong reason for believing that Fitch was the pioneer, yet the first practicable steamboat was the Clermont, constructed by Robert Fulton in 1807. The Clermont, originally a canal boat, was built to run on the Hudson. In order of construction the Clermont was the sixteenth steamboat, but it was the first to be used permanently. The trial was made August 7, while throngs of people crowded the banks to watch the sight, a few praying for success, but most of them certain that it would be a failure. There was a slight delay, but the boat went ahead on her trip and steam navigation was an accomplished fact. Along her route she was met with various emotions. Many people feared her and ignorant country folk believed that the devil was coming up the river after them and took to the woods with their guilty consciences.

The Clermont was a crude boat. She was 133 feet long, 18 feet beam and 160 tons and made only five miles an hour. But within a year two other boats built by Fulton were running between New York and Albany, the time being thirty-two hours, with a fare of $7. The success of the experiment led to its imitation in England. The Comet was launched upon the Clyde in 1812. It was forty feet long and had a three-horse power engine.

These steamships were an important factor in the development of the newly settled portions of the United States. Before the days of the steamboat, methods of transportation were primitive. For the most part settlers made their homes along the banks of the great rivers of the Western country. Their boats were at first composed of such materials that after going down stream they could be broken up and sold as lumber. Keel boats for the purpose of ascending streams followed and these were propelled by long poles in the hands of the boatmen. Standing on the gunwale at the extreme bow of the boat the boatmen thrust the pole into the mud, and setting their shoulders against the top pushed the boat forward with the feet in walking toward the stern, which reached, he would draw up the pole and repeat the movement. In this laborious mode of travel all the merchandise sent from the East via New Orleans reached its destination. Four months were required for the journey from St. Louis to New Orleans. At Pittsburg in 1811 the first boat for Western rivers was built and she made the trip to New Orleans. Great enthusiasm was aroused when, with the construction of the Enterprise in 1815, St. Louis was reached in twenty-five days from New Orleans. The opportunity which was given for the development of the country excited the imagination of the people. A Cincinnati writer of 1817 thought that the time might come

FIRST RAILROAD TRAIN IN ENGLAND

when 40,000 families would be living in the 10,000 miles of territory which he counted as tributary to that city.

It was not until 1826 that the first steamer ran up the Allegheny River and in the same year the ship Illinois reached St. Louis from New York via New Orleans, 3,000 miles in twenty-nine days and a half. From that time dates the palmy days of steamboating. Then began the exciting races which have been made immortal by the clever pen of Mark Twain. In 1823 the time between St. Louis and New Orleans had been reduced to twelve days, in 1828 the General Brown made it in nine days and four hours, and in 1860 the running time had been reduced to three days. Now the steamboat has practically vanished from the Western rivers. The railroad has taken its place. But it survives on the great lakes of the North, where there is an enormous traffic.

The first steamer to cross the Atlantic was an American built ship, the Savannah. The vessel had been built in New York as a sailing ship. She was 350 tons burden, clipper built, full rigged and propelled by one inclined direct-acting low pressure engine, similar to those now in use. She had paddle wheels that could be taken out and put on deck. The Savannah steamed to the city in whose honor she was named and from there started for Liverpool May 24, 1819, making the voyage in twenty-five days, being under steam eighteen days. She used pitch pine as fuel, the use of coal in American steamers not having been introduced at that day. From Liverpool she went to St. Petersburg. For some years she ran between Savannah and New York, and finally ran aground in a storm off Long Island and went to pieces.

A ship wholly dependant upon steam was regarded for a long time as a mere chimera. Nautical experts insisted that no vessel could carry fuel enough to supply her

engines on a long voyage and this was long accepted without dispute. The first vessel to make the journey without the use of sails and by steam alone was a Canadian vessel, the Royal William, built at Three Rivers in the Province of Quebec. She sailed from Quebec August 5, 1831, for London, putting into Picton en route and arrived at Gravesend September 16, after a voyage of 25 days from Picton.

Yet in spite of this Dr. Dionysius Lardner declared that "As well might they attempt a voyage to the moon, as to run regularly between England and New York." This feat was accomplished by two British vessels in 1838—the Sirius and the Great Western. The former was 178 feet long and of 703 tons and the latter 256 feet and of 1,340 tons. The average speed of the former was seven knots and the latter 8.2 knots an hour.

America lagged behind England in the steam Atlantic trade. It was not until 1847 that the first American steamer was built expressly for the transatlantic trade. She was the United States, built at New York for the Black Ball line. The United States was a wonderful vessel in those days, being 256 feet long and of 2,000 tons burden. Her first voyage, made to Liverpool, occupied thirteen days. Seven years before, in 1840, Samuel Cunard began running ships from Liverpool to Boston, the Britannia, the first of the line, making the trip in fourteen days and eight hours.

In 1840 began the use of the screw propeller, and the construction of ships of iron. Captain John Ericsson is given the credit for the invention, but although he was the first to succeed in the application of the principle it had been suggested and attempted by others in previous years. Ericsson built a small screw steamer in 1837 and invited the English lords of the admiralty to make a trip in his

boat, which made ten miles an hour. But the board gave him no encouragement and one of the members said: "Even if the propeller had the power of propelling the vessel it would be found altogether useless in practice, because the power being applied to the stern it would be impossible to make the vessel steer." Paddle wheels were universally used then, although now they are seldom or never seen on the ocean, and are used merely in rivers and other places where the paddle wheel is more satisfactory because of the shoals. Ericsson built a small steamer, seventy feet long, in 1839; he then came to America to develop his idea, and in 1841 designed the Princeton, the first man of war with a screw propeller. In the same year he designed the Vanadalia, the first screw propeller vessel constructed for business purposes, which was built at Oswego, N. Y., and navigated the Great Lakes. Gradually the principle of the screw propeller established itself and screw steamers were built both in America and England and employed in the coasting trade and in short sea voyages. But it was deemed a hazardous experiment to try and cross the Atlantic, especially in the winter months. The Great Britain, launched on the Mersey in 1843, was the first transatlantic steamer on which the principle of the screw propeller was applied. The Great Britain was designed by Brunel and was 332 feet long and of 3,200 tons.

The Great Britain is also remarkable in that Brunel substituted iron for wood. The metal had been used for hulls of river steamers as far back as 1820, but had not come into general use. To-day over 90 per cent of the steamers built in Great Britain each year are of iron, and the wooden ship is a relic of the past. This substitution of iron for wood gave a severe blow to the American merchant marine, and in

fact one from which it has not yet fully recovered. When ships were made of wood the forests along our coasts furnished unusual opportunity for ship-building, and America indeed became queen of the seas. But the mineral resources of the United States were not sufficiently developed when the change came from wood to iron and the merchant marine of the United States suffered. This is, however, also due to the fact that the United States was occupied chiefly in internal development and railroads, manufactures and mining absorbed our attention, to the exclusion of foreign commerce. In recent years, however, there has been a great increase in shipbuilding, although this is still one of the few things in which the United States lags behind in the march of progress. With the improvements in steel it supplanted iron, it being better for every purpose.

Water-tight compartments had been used in wooden ships, but they were not practicable. The use of iron, however, made it possible to make use of this device by which the vessel is divided by bulkheads, and thus, while two or even three of the compartments may be open to the sea the vessel will still float. The Royal William was the first important steamer to use water-tight compartments.

The increase in speed of steamships has been due chiefly to improvements in the marine engine. The new steamer Deutschland, of the Hamburg-American line, work upon which was begun in 1898, has a horsepower of 33,000, while Fulton's Clermont had a horsepower of only 24. There has been great economy in fuel. Steel has made engines stronger, and greater piston speeds with higher pressures have been made possible. Piston speeds have increased five fold, and boilers stand twenty times as great a pressure. All of these tend toward increased

speed. The single engine was succeeded by the compound and the compound by the triple expansion.

With these improvements came increase in the size of vessels, this being because large vessels are relatively more economical in fuel. While the Great Eastern, the largest vessel built, was successful only in its mission of laying the Atlantic cable, the increase in size has been truly remarkable. The world's greatest liner, larger even than the Great Eastern, the steamer Oceanic of the Oceanic Steam Navigation Company's line, was launched in January, 1899. Her gross tonnage is 17,040, displacement, 30,100 tons; length over all, 704 feet, by 68 feet beam, by 49 feet 6 inches moulded depth. The total depth is about 68 feet, and the length between perpendiculars about 685 feet. There are fifteen boilers—twelve double and three single-ended—of about 1,100 tons total weight. The engines are triple, four cylinder, four crank balanced, of about 28,000 indicated horse-power. While the largest ship afloat, the Oceanic is not the fastest. The Deutschland, of the Hamburg-American line, when completed (1900), will be the swiftest passenger steamer afloat. The vessel has a length of 663 feet, breadth of 67 feet, and a depth of 44 feet. She will be fitted with two six-cylinder quadruple expansion engines, indicating in the aggregate 33,000 horse-power. For supplying steam to the engines twelve compound boilers with eight furnaces each and four single boilers with four furnaces each will be provided. The speed contracted for is 23 miles an hour, but it is expected that 25 miles an hour will be reached.

The introduction of steamships has brought forth inventions of all sorts for the improvement of their navigation and manipulation. So perfect are the liners now in use that the ocean greyhound may be stopped or reversed by a child, while a single man is able to execute

the order "hard a-helm" on a man-of-war going at full speed. Before the new hydraulic machinery was invented, three score men were barely sufficient to stop a fast steamer in full career. Thirty feet a minute is the usual rate at which model anchor engines raise the heaviest anchors in use. The hold of the vessel is illuminated to its farthest recesses by electric light, and the constant risk of fire from lanterns or lamps upset by the rolling of the ship is entirely done away with. Science balances the compasses so as to avoid all danger of their variation, that variation which previous to the discovery of the modern method of compensation wrecked so many stout vessels upon unexpected reefs. Steamers at full speed take soundings to the depth of 100 fathoms, as a matter of course. The steam siren shrieks automatically at regular intervals in a heavy fog, and, last, but not least, when the good ship makes port, steam rings her bells, winds her cables around the capstan and runs the derricks which unloads her cargo.

Safety has been of first consideration from the first, and statistics are quoted to prove that ocean travel is now no more dangerous than a railroad journey.

Comfort as well as speed and safety are results sought by the builders of ocean-going steamers, and the great vessels on the lakes that cater to the traveling public. In 1838 even the best kind of ocean traveling was excessively disagreeable. The supply of fresh food became exhausted a few days after leaving port. But there is now a complete revolution in this respect. Even the steerage passengers fare better than did the cabin passengers of the early days. The employment of cold storage and artificial refrigeration, together with the adaptation of every improvement in life ashore, have arranged it so that a voyage on the ocean may be as comfortable as life at a first-class hotel.

Only the motion remains to worry the person who is addicted to sea-sickness.

The fable of Jack's beanstalk is more than realized by the evolution of the steamboat. It is a far cry from the Clermont, built by Robert Fulton in 1807, to the floating hotel which crosses the Atlantic from New York to London in six days, carrying every modern luxury for the benefit of her passengers, and the Iowa or the Oregon, those triumphs of modern science as applied to naval warfare, which have so immeasurably increased the respect of the universe for the United States and her navy. Sailing vessels are old-fashioned; steamships navigate every sea on the face of the earth, penetrate every bay and inlet, find the head of navigation on every river, and darkest Africa finds the electric light turned full upon it from the modern gunboat which terrorizes her most warlike tribes.

Mulhall estimates that the shipping of the world is of 22,885,000 tons register, of which 11,905,000 is steam. More than half of the aggregate is British and American, the United States being second in the list. Together the ships of the world have a carrying power of 58,610,000 tons.

The problem of traversing space by means of apparatus under navigable control has for many years occupied the minds of inventors. Success in this direction has not been great, but the Century has made easier the way of those who are striving to attain the end. Ballooning, which involves the use of machines lighter than the air, does not present insuperable difficulties. Since the Brothers Montgolfier ascended in 1783 by means of a fire balloon at Annonay, there has been no difficulty in making ascents of as great as five miles. The first successful attempt at propelling balloons was made by Giffard in 1852, the car being little more than a wooden platform with

wheels to allow its running along on descending. More difficult has been the problem of aviation or the use of flying-machines, because of the necessity of using apparatus heavier than the air. One of the characteristics of aviation is a large supporting surface, either in the form of wings or an æroplane which is used to carry the weight. Machines of this type invented by Langley, Maxim and others have made short flights successfully, but they are as yet far from practicable, although these men, both distinguished scientists, believe that the problem will be solved before many years shall have passed.

As fascinating is the subject of submarine navigation. Many attempts have been made to solve this problem, and the nearest to success was achieved by the Holland submarine boat, designed as a war-vessel for use in the war between the United States and Spain. The boat, although it made several trips under water, was not regarded as feasible by the navy department, and submarine navigation is not yet an accomplished fact, although the boat built by George C. Baker in 1892, and others, are steps in that direction.

COMMUNICATION

A man in Florida may now send a letter to his friend in the Klondike gold fields for two cents, or for five cents he may send a letter to his friend in Australia. The development of the post-office has made this possible. Sixty years ago, even if communication had been open between these districts, such a feat and such a price was an impossibility. There are those who say that penny postage, as it is called from the English coin of the value of two cents, is one of the greatest achievements of the Century. There is certainly nothing that has conduced more to the comfort of the people.

Post-offices are as old as history. Communications were sent either by couriers, pedestrians or in vehicles, but the splendid postal organization which now exists was then beyond the imagination of the man who lived at the beginning of the Century. There had been little development since the dawn of civilization. Relays of fast post horses shortened the distance, but in Washington's first term as President, the mails traveled at the rate of only four and a half miles an hour. The rates of postage when the post-office department was established under the constitution were: For thirty miles, six cents for one letter sheet; for sixty miles, eight cents; for 100 miles, ten cents, and so increasing with the increased distance to the maximum, twenty-five cents for distances over 450 miles. The mails were once a week or once a month, and "reply by return post" had a real meaning.

The development of the post-office has kept pace with the improvements of the means of communication,

although perhaps this is not strictly true of the United States, where the telegraphs and telephones, unlike in most other civilized countries, are not under the control of the post-office department. There is no need to repeat the story of the development of the post-office in rapidity of the transportation of mails. That would be a repetition of the story told in the previous chapter dealing with the achievements of the Century in the matter of transportation. The cheapening of postage is the postal achievement of the Century, and the rapid adaptation of more speedy methods is an incident.

To England the world is indebted for the placing of correspondence by mail within the means of everyone. Sir Rowland Hill noticed that, although the population of England had increased 6,000,000 during the twenty years from 1815 to 1835, the postal receipts were slowly diminishing. To overcome this the postal authorities had increased the postal rates, but this led to a further decrease in receipts, and means were found to defraud the post-office. As the charge on the letter could not be paid by the sender, those away from home arranged codes of signals which should tell their friends of their welfare. All that was necessary was to send an empty envelope, which would be refused at the door. Newspapers with words underscored were also used, as they were sent through the mails free, a stamp tax being levied upon them. The finance accounts for the year showed that about one-fifth of the letters transported were "refused" by the persons to whom they were addressed. The price of a letter of a single sheet, weighing less than one ounce, was from 4d for the smallest distance to 1s 8d for the longest. If there were any enclosure the charge was doubled, and to ascertain this, letters were subjected to a strong light, temptation thus being put in the way of the officials. To

evade the postal charges, friends were made to carry parcels, proof-sheets and letters; carriers made illicit posting a regular business. There was an endless amount of red tape. Each letter had to be weighed and examined for enclosures, marked with the amount of postage due, which the postman must wait to collect, and as there were as many as forty possible varieties of inland rates, it required much office work and consumed much time.

Hill made a study of the problem and found upon examination that the expense of a letter did not vary appreciably in proportion to the distance carried. He found that the expenditure which hinged upon the distance the letters had to be conveyed was £144,000, and that which had nothing to do with the distance was £282,000. Hill further found that the average cost of a letter was less than one penny, and he urged that a uniform charge of 1d (two cents) be made for the carriage of a letter, claiming that there would be an enormous increase in correspondence. The idea met with warm support among business men, but it was bitterly opposed in parliament; not on the grounds that correspondence would fail to increase, but on the ground that it would develop to impossible proportions. Lord Lichfield ridiculed the idea of the post-office ever being able to carry all the letters that would be sent; to which Hill replied that he had never before heard of a business man who feared too great an expansion of business.

Penny postage finally became a fact and was in operation on January 10, 1840. In the first two years the number of chargeable letters rose from 75,000,000 to 196,500,000, and every year the loss of the department was reduced.

In 1800 there were 903 post-offices in the United States. The last report of the postmaster general places

the number at 73,570. In 1800 the annual revenue of the department was $280,804; during the fiscal year ending June 30, 1898, it was $89,012,618. In respect to the distance for which a letter is conveyed for two cents the United States is now the cheapest postal system in the world, but in the matter of cheap postage the United States was far behind Great Britain. Until 1863 the distances over which the mails were carried was the basis of the rates of postage. In 1845 the rates were: Not exceeding 300 miles, five cents; exceeding 300 miles, ten cents. By a law of 1851 the distance for which the minimum rate was charged was increased to 3,000 miles. The uniform rate of three cents was made in 1863, and in 1883 it was reduced to two cents, the rate which had been in force in Great Britain for forty-three years. The weight carried for the two-cent stamp was increased from a half ounce to one ounce in a few years, making a further reduction in the cost of communication by mail.

The money order system introduced in England in 1792 by a private company was adopted by the British post-office in 1838. The system was not employed in the United States until 1864. There has been a gradual reduction of fees, and during the year ending June 30, 1897, the money order business of the United States amounted to $174,482,677, and there were 20,031 offices where they are sold. In 1865 the number of offices was 419, and the value of money orders issued was $1,360,123.

The little bits of colored paper that are one of the principal adjuncts to the postal business were first used in England in July, 1840, and came into use in this country in July, 1847. There are now said to be as many as 9,300 varieties—some, of course, obsolete, and including the stamps on newsbands and those used as revenue stamps. Postal cards were first issued by Austria, and in

the year 1870. They were adopted by the United States in 1873. In 1897, 523,608,250 were used in the United States alone.

The registry fee, which was half a crown originally in England, has there been reduced to four cents. The system was adopted in the United States in 1855, and the fee made ten cents, which has since been reduced to eight cents. In the United States the free delivery system was authorized in 1885. Railways were first used by the United States for postal purposes in 1834. Other reforms have been the introduction of railway post-offices, electric street cars, and pneumatic tubes.

The post-office does many things in other countries that it does not do in the United States. The parcels post was introduced in Great Britain in 1883, and transports small packages at a small charge. Most European countries now have a system of sending packages by mail cash on delivery, similar to our express companies. The telegraph business is a part of the post-office abroad. In continental Europe, moreover, free delivery extends even into the rural districts. The United States is almost alone among civilized nations in its lack of the postal savings bank, which institution, for the benefit of small depositors, especially in the rural districts, was introduced by England in 1861. The pneumatic tube was first used in London in 1858, and in Boston in 1896.

The crowning triumph of the postal service was the establishment in 1874 of the Universal Postal Union, which includes nearly every nation with a post-office. Five cents is now all that is necessary to carry a letter to the uttermost part of the earth. An idea of the extension of the post-office may be obtained by a glance at the Congo Free State. The post-office department of that vast country was organized in 1885, and ten post-offices

have since been established, making it possible to send a letter at a cost of five cents to the wilds of Central Africa. The cannibals who reside on the banks of the Arumwi River enjoy all the advantages of the Postal Union if they so desire.

There are now scattered over the various countries of the world more than 271,000 post-offices, of which the largest number in any one country is 73,570, in the United States. There are 440,500 letter boxes from which collections are made. The total number of persons employed in the world's postal service is 872,400. Figures scarcely convey an idea of the magnitude of the business that is annually transacted through the world's post-offices. The fact that over eight and a half billion—or to give the exact figures, 8,514,874,495—letters were distributed in the various countries, is almost beyond comprehension; other pieces of mail matter of various kinds raise the total amount of mail handled to 15,066,033,246 pieces. The total value of money orders issued in a year is $2,805,000,000; of these the largest number issued in any one country was 96,037,953 in Germany. The postal savings bank business has reached its highest development in Great Britain, where the total amount to the credit of depositors is in excess of $500,000,000.

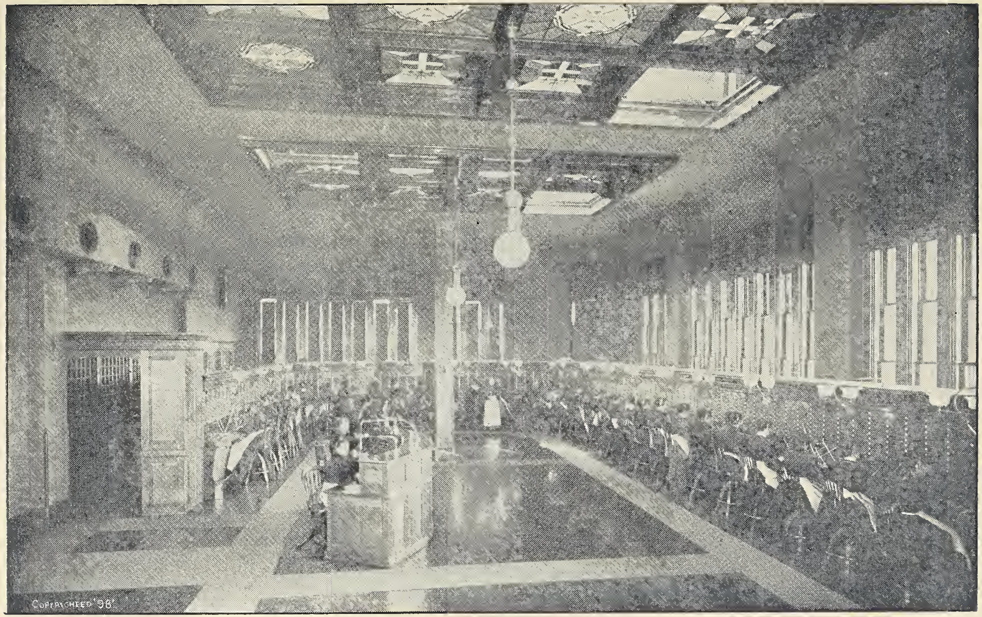
Long a dream of the imagination, the telegraph found its realization in the Nineteenth Century. Laplace suggested the idea of signaling by means of breaks in electrical currents. His idea was seized by others, and in 1832 Schilling, a Russian, devised a system of telegraphy in which thirty-six needles were used. Gauss and Weber, two German physicists, established a line about three miles long at Göttingen; and Steinheil, working on their ideas, constructed several telegraph lines radiating from Munich. Steinheil was the first to make use of the earth

as a return current, thus using a single wire to carry each current, and connected to the earth at both the sending and receiving stations. Wheatstone, an English inventor, together with William F. Cooke, in 1836 took out a patent for a needle telegraph. As described in their first specification, their system required five needles and six wires, one of the wires being used as a common return for the other wires. By various combinations of the needles, all of the letters and numerals could be represented. They soon found, however, that they could do all of the work by a single needle. The Wheatstone telegraph was tried successfully between Euston and Camden Town stations on the London & Northwestern railways, on July 25, 1837.

It was two years later, in 1839, before the first telegraph for public use in the world was opened. Wheatstone constructed a line between Paddington and Slough, a distance of twenty miles. The wires were suspended on posts in goose-quills. Commercial business was taken, but evidently the income of the line was derived from the exhibition of its working. Although admission was only a shilling, and children half price, it was not well patronized until its fame was spread abroad by the capture of a murderer through its aid. The murderer, after killing a woman at Slough, took a train for Paddington. His description was telegraphed, and to his astonishment he was arrested on his arrival there.

These early telegraphs were impracticable, and the credit of the invention of the electro-magnetic telegraph, which is the basis of the one used to-day, belongs to Samuel F. B. Morse, who began his experiments as early as 1832, after some conversation on board ship while returning from England. Although an artist and a sculptor, Morse had some practical knowledge of electro-magnetism gained from his studies at Yale College, and he now de-

voted all of his time to an attempt to perfect the telegraph, although as a means of livelihood he retained his chair as professor of designing at the University of New York. In order to economize his scanty means, he slept and took his meals, prepared by himself, in his studio. His first practicable instrument was perfected in 1836. It was a clumsy affair. His friends laughed at him, as inventors have always been laughed at, and he received no encouragement, but was ridiculed for spending all of his meager income on the useless toy. A caveat was filed at Washington, and in February, 1838, he, with Alfred Vail and Professor Gail, took the instrument to Washington and exhibited the telegraph on a ten-mile circuit to President Van Buren. They then asked an appropriation of thirty thousand dollars for an experimental line of fifty miles, but the appeal was not acted upon by Congress. For two years he wandered about Europe, trying to secure patents and aid. On his return he found that his partners had met with financial reverses and were unable to help him. He went to Washington in 1841, and set up his instruments and strung his wires. In the direst poverty, he explained his invention to Congressmen, who were amused, but regarded it merely as a toy. Finally, when he had only 37 cents left in his pockets, he secured the influence of a class-mate, who undertook to get the appropriation through Congress. It was passed on the last day of the session, at a few moments before midnight, and after eight years of waiting, Morse had what he had sought—an opportunity to show the world what he could do. Then began the construction of the line from Washington to Baltimore. When ten miles had been laid in pipes, it was found that the current grew weaker. The fault was due to induction, the carrying away of the electricity by the earth, and it was after much discussion that Vail's idea



SWITCHBOARD — TELEPHONE EXCHANGE

of stringing the wires on poles was adopted. On May, 1844, Morse was able to fulfill the promise he had made to Miss Annie G. Ellsworth, that her message should be the first sent over the line. In the presence of distinguished officials of the government, the message was sent. It was "What hath God wrought?" It became famous, and we are not yet sure of the answer.

The telegraph as devised by Morse was crude. To his partners is due much of the development of the idea. He first used a single cell, and Vail suggested a rectangular wooden box, divided into eight compartments and coated inside with beeswax, so that it might resist the action of acids. Morse knew nothing of what is known as the Morse alphabet. His complicated system as described in his 1837 caveat consisted of a number of signs by which numbers and consequently words and sentences were to be indicated. There was then a set of type arranged to regulate and communicate the signs, and rules in which to set this type. A crank turned by hand regulated the forward movement of the type. The writing apparatus made marks on a slip of paper. Vail discarded this and invented the dot and dash alphabet, which is now in universal use.

The receiving instrument, as finally perfected, consisted of a cylinder over which a strip of paper was run by clock-work, and in which indentations were made by a small metal peg on the arm of the armature. The latter was held slightly away from the magnet core by a strong clasp when no current was passing; but when the impulses from the transmitter came over the line, and passed through the magnet coil, the core attracted and released the armature in rapid succession. The length of the marks on the paper is in direct proportion to the duration of each current impulse the operator lets over the line by the working of the key. To avoid the need of a strong current on

the line, the recording instrument was placed in a local circuit with its own battery, the current of this being governed (opened and closed) by the line magnet—which then acquired the name by which it is now known—the relay. Sometimes on long lines this relay magnet is made to let on a fresh current in similar impulses from the battery in some office midway of the line, which is called the repeater.

In the very beginning the recording instrument was replaced by the sounder, which was also of Vail's invention. The operators became so accustomed to the tapping that they read the message by sound. The managers tried at first to prevent it, and Morse was most vigorous in opposing the innovation, but Vail improved the sounder, and the recorder was discarded. Now the telegraph appeals to every sense, for a deaf clerk can feel the movements of a sounder, and the signals of the current can be told without any instrument by the mere taste of the wires inserted in the mouth.

During the month of May, 1844, another opportunity for conspicuously demonstrating the value of the telegraph occurred when three important national conventions were held in Baltimore, and the news of their proceedings was instantaneously transmitted by the electric current to eager crowds of congressmen and others at the national capital. For one year the telegraph line was operated gratuitously, and then a small charge was made for messages by the postmaster-general, under whose direction it was. The government was offered the invention for $100,000, but declined to buy it, and the development of the telegraph was left to private enterprise.

The improvement of the telegraph was rapid during the next decade. By 1847 a telegraph line ran from Washington to Albany, with many branches. Lines were built

on the Morse system in every part of Europe. The increase in business, due to the desire of the public to transact its business by electricity, made necessary either the construction of many more lines or the devising of some system by which more messages could be transmitted over the same wire. Moses G. Farmer, of Boston, about 1852 made some experiments, but not successfully, and the method at present in use for multiple transmission was first suggested by Gintl, of Vienna, in 1853. Joseph B. Stearns, of Boston, in 1872 invented the duplex system, by which two messages, one each way, could be sent over a single wire simultaneously. Stearns' system was improved in 1874 by Thomas A. Edison, and it became possible to send two messages the same way over the same wire. Elisha Grey, of Chicago, in 1875, designed a system of multiplex telegraphy for the simultaneous transmission of several signals. In principle the system depends upon the synchronism of sonorous vibrations, propelled by electric currents. The Stearns and Edison systems were combined to form the quadruplex, by which four messages, two each way, could be sent at the same time over a single wire. In 1898 Professor Rowlands, of Johns Hopkins University, perfected a method by which twelve messages may be sent simultaneously over the same wire.

Besides the Morse system of telegraphy, there are several automatic telegraphs, by which the message is sent with great velocity by running a previously perforated fillet of paper through the transmitter—electric contact being made through the holes, the process being the same as in the musical instrument known as the orchestrion. There is also a machine telegraph, perfected by Hughes in 1881, in which the electro-magnet on attracting its armature, presses the paper against a revolving type wheel and

receives the print of a type, so that the message can be read by a novice.

To-day the telegraph has developed to an enormous extent. The length of the world's telegraph system in 1897 was 4,908,823 miles, of which more than half was in America. In Great Britain the telegraph is most used, the telegraph rates being only six-pence for an ordinary message, and over 83,000,000 messages were carried during 1897. The telegraph has even reached Africa and the remote parts of Asia. The savages still marvel at the wonder of electrical communication. It is said that the Chinese, frightened at the "evil spirits," used to cut down the poles until Li Hung Chang ordered that whenever a pole was cut down, the man whose house was nearest to it should be beheaded. This proved an effective way of making him keep watch, to prevent the cutting down of the pole.

An interesting development of the telegraph which has been utilized on railroads in the United States and Great Britain, is the ability to send messages from moving trains. This invention owes its origin to Phelps, and was improved by Edison. The signal currents are intermittent, and when they pass through a conductor on the train they excite corresponding currents in wires running along the track.

Since the beginning of telegraphy, attempts have been made by various inventors to communicate without wires, and while no practical result has as yet followed these experiments, the future holds out great possibilities of ultimate success. Joseph Henry, of Washington, found in 1842 that when he threw an electric spark an inch long on a wide circuit in a room at the top of his house, electrical action was instantly set up in another circuit in the cellar. Visible means of communication between the two

circuits being absent, he reasoned that the electric spark produced some kind of action in the ether, and, passing through two fluids and ceilings 14 inches thick, caused induction in the wires in the cellar.

Edison's application of induction to telegraphy from moving trains, and Hertz's discovery that electric waves penetrate wood and brick, but not metal, are the bases upon which inventors of the past two years have worked. These have been carried to the furthest stage of promise by one Italian electrician, Guiglielmo Marconi, while at work in the laboratory of Prof. Riglio, of Bologna. He is mainly indebted for his experiment to W. H. Preece, Director of the English Postal System. His official position has enabled Mr. Preece to thoroughly test it in the British Post-Office Department, and these tests have been successful. The Marconi system of telegraphy depends not upon an electrical magnet, but on electrical vibrations —that is to say, on electrical waves—set up at a rate of 250,000,000 to the second. These vibrations travel through space in straight lines, and can be reflected and refracted like light—indeed, they are capable of all the phenomena of which light is susceptible.

The invention which dealt with the method of receiving and sending messages by this means was first experimented with on the roof of the post-office, and then for three-quarters of a mile on Salisbury Plain. Marconi was present that night, and this was the first occasion on which the apparatus was shown, except to government officials. The great difference between the systems, which had already been tried, and that of Mr. Marconi, was that in the former a wire on each side was necessary, while in the latter no wire was required. Vibrations were simply set up by one apparatus and received by the other, the secret being that the receiver must respond to the number of

vibrations of the sender. The apparatus was then exhibited. What appeared to be just two ordinary boxes were stationed at each end of the room, the current set in motion at one, and a bell was immediately rung in the other. "To show that there was no deception," Mr. Marconi held the receiver and carried it about, the bell ringing whenever the vibrations at the other box were set up.

The most valuable use to which telegraphy without wires is likely to be put in the near future is communicating from ship to ship at sea, or between lightships and lighthouses; which will not only add to the convenience of navigation, but render it more safe.

Practical use has not yet been made of the telautograph, which is the name given to the apparatus for the transmission of sketches and drawings by wire. The most successful of these inventions is that of Elisha Gray, of Chicago, which was put to practical use by the Chicago Times-Herald, on June 22nd, 1895. Using the ordinary telegraph wires, the Times-Herald was enabled to receive exact facsimilies of letters written in Cleveland by men in attendance at the national convention of Republican clubs. The fact that telegraphic sketches have not since come into general use shows that the telautograph has not yet reached a condition of real usefulness. In Prof. Gray's instrument, which was exhibited at the World's Fair, there is a pencil connected by small, rigid steel rods. As the operator draws on the paper the letter or drawing which he desires to produce, the instrument's currents or electrical impulses are awakened that excite electrical magnets and move the stylus at the far end of the pen. An invention called the Telegraph Pen, devised by E. A. Cooper, of England, is somewhat similar, though less reliable. It is based on the method of varying strength of current in the curves of the hand writing.

Even before Morse had succeeded in obtaining connection between Baltimore and Washington, inventors were at work upon methods for establishing communication through bodies of water as well as over stretches of land. The two banks of the Hoogly River in India had been connected as early as 1839 by a Mr. O'Shaughnessy, who made use of an insulated wire plunged into the stream. Wheatstone proposed to connect Dover and Calais by submarine telegraph cable in 1840, but it was ten years before the plan was realized, and then the cable broke, after transmitting only a few signals. In 1851 a new cable was laid. The development of submarine telegraphy was chiefly delayed by the difficulty of devising protection and insulation for the wire. Gutta-percha was used for this purpose in 1848, and the cable was laid across the Hudson River from Jersey City to New York. The cable was strengthened by a covering not only of gutta-percha, but by a layer of tarred hemp, which in its turn is covered and protected by galvanized iron wire twisted around the core.

Cables of increasing length were laid, but the Atlantic Ocean still seemed an insuperable barrier between Europe and America. To Cyrus W. Field was due the realization of what had long appeared an impossible project. He organized a company for the purpose in 1854, but it was twelve years before they succeeded. These twelve years were filled with disappointing failures, which, however, did not daunt the indomitable pluck and energy of Mr. Field and his associates. The first attempt was made on August 7th, 1857, by the United States frigate Niagara, which sailed from Valencia, Ireland, in the direction of Heart's Content, Newfoundland. The cable broke when about 400 miles had been laid, and the steamer returned. The next year another attempt was made. This time two

ships separating in mid-ocean, proceeding shoreward, one to the east and one to the west, each laying cable as they separated. Again the cable broke; but a third attempt was made later in the year, which saw the whole distance successfully spanned, and on August 16, 1858, Queen Victoria and President Buchanan exchanged congratulatory messages. Great was the joy over this triumph, but it was of short duration. Day by day the messages by the cable grew more indistinct, and finally ceased. Though laid, the cable was a failure.

Field was not discouraged, but his associates were, and for eight years the cable remained useless at the bottom of the sea. During this period the United States was torn with civil war, and the sympathy of Great Britain for the Confederate states aroused an enmity in the hearts of Americans which checked any desire for closer communication between the two countries. In spite of discouragement and previous failures, Field succeeded in reorganizing his company and making a new cable. The steamship Great Eastern, which was unavailable for ordinary uses of commerce, was chartered, and in this giant vessel a cable 2,273 nautical miles long, and weighing 300 pounds per mile, was stowed. More than half of it had been laid when the cable parted, and the broken end disappeared from view. Attempts to secure it proved futile, and the Great Eastern returned to Europe. Five cables were now at the bottom of the Atlantic Ocean, and they represented an expenditure of millions of dollars. Still Mr. Field did not despair, and he persuaded his associates to invest a still larger sum. Again the Great Eastern made another journey with a new cable, equal in length to the old. She started from Queensland, and without further serious misadventure, accomplished the whole distance on July 27th, 1866. Telegraphic communication with Europe

has been uninterrupted since that time. No greater triumph of engineering skill has ever been accomplished, nor can there be pointed out a more forceful object lesson in pluck and perseverance.

Since then the world has been girdled by cables. Communication has been made possible to the uttermost parts of the earth. When all the lines are clear it takes about 15 seconds to send a single sign from London to New York. There are now altogether 318 cables, with a total length of 146,419 miles. The great Pacific Ocean is as yet uncrossed, but plans are being arranged for the spanning of that mighty chasm. The principal improvement in the electrical outfit of the cable system has been the adoption of more delicate instruments to the transmission and reception of messages, as cables are generally worked on the condensed system, there being no metallic circuit.

The laying of cables is expensive. The probable cost cannot be far from $1,000 per mile; this includes the making and the laying of the cable. Present experience gives from thirty to forty years as the probable length of life of a modern submarine cable, but much depends on the preparation of the outer strands of wire, especially the galvanizing. There are instances where a cable has lasted only ten years. Specially equipped steamers are required to lay cables, and submarine wires are constantly sustaining damage from some cause. It is necessary to have one of these cable ships always ready for service.

Messages are not sent by the Morse system, but on an adaptation of the Wheatstone system, which prints a waved line on a strip of paper. The Morse system cannot be used because of the peculiar construction of the cable itself, and of a certain eccentricity of the electrical current when acting under long distances of water. Electricity

invariably seeks to escape from its conductors to the earth, and, well insulated as the cables are, the innumerable ocean currents would make impossible a succession of vibrations without breaks in the electric current.

Great as the telegraph is, still greater is the telephone. By it articulate speech, with all its shades of tone and quality, is so accurately transmitted and reproduced that the voice of a friend speaking at a great distance can be easily recognized. In the United States alone the use of the long distance telephone has brought forty million people within speaking distance of each other. There is no more remarkable achievement of science than this. The speech of the telephone is as great an improvement over that of the telegraph as is the conversation of men over the chatter of monkeys.

But the telegraph did not suggest the telephone, and the two inventions have run along entirely different lines. Its first basis was the discovery of Page in 1837, that when substances are magnetized they emit sound. Philip Reis, a German school teacher, in 1860, utilizing this principle, managed to transmit both words and music over a short distance. Reis's experiment set several inventors at work along these lines, and the present electro-magnetic telephone was invented at about the same time by Graham Bell and Elisha Gray, both Americans. Bell's telephone is the one now in use. He exhibited his invention at the Philadelphia Centennial in 1876. By this it was made possible for two people to talk over a single wire for a distance of ten miles. Its principle was not the transmission of speech, but the mechanical reproduction thereof by means of the rattling of a piece of iron close to the listener's ear. The transmitter has a membrane, bearing on its center a small piece of iron placed opposite the poles of the electro-magnet. The receiver, in which is enclosed

an electro-magnet, has fixed in the top a thin disc of iron, left free to vibrate. Sounds are produced by the vibration of this disc corresponding to currents of electricity from the other end.

Many improvements have been made in the arrangement of the receiver and transmitter since Bell's instrument was invented, with a view to intensifying the effect in the receiver. Most important of these improvements is that of Prof. Hughes, who in 1878 discovered that if one piece of carbon be allowed to rest upon another and an electrical current be passed from one to the other in a circuit containing a Bell receiver, the lines will respond to very minute sounds in the vicinity of the carbons. This is called the microphone, and is in most transmitters. Copper wire instead of iron is used for trunk lines of telephones, because it is inductive, and the Bell telephone is extremely sensitive—so much so that conversation over one wire can often be heard on a neighboring wire.

The original telephone which made possible conversation between one person and another at a distance of ten miles, has been improved so that large numbers of persons are enabled to inter-communicate at will. This is due to the switch board, the aggregation of many inventions. Switch boards are often enormous in size, and represent thousands of dollars in value, while hundreds of miles of wire are often used in their construction. In New York City 37,000 subscribers are put in communication with each other through this switch board, and by means of other switch boards are enabled to talk to other subscribers at Chicago or at Boston. The connection is made by women whose duty it is to attend to the switch board. When a subscriber rings the bell a disc, bearing his number, drops, and then the operator inquires what the subscriber wants. When the number desired is men-

tioned, she takes up a pair of brass plugs, coupled by a flexible conductor, and joins lines of the subscribers in the switch board by simply inserting the plugs into holes corresponding with the wires, which is a very simple operation. In the near future the telephone girl, who has supplied writers of fiction with many romantic heroines, is likely to be supplanted by some other labor saving device. Already patents have been taken out for automatic machinery designed to connect subscribers, and telephone experts predict that the use of such a contrivance will become universal within a few years.

The last decade of the Nineteenth Century has been remarkable for the extension of telephone lines, and with improvement and stronger wires electricians believe that communication will be possible from one end of the United States to the other. The chief question is whether the results would be justified by the business. Extensions have been made wherever this condition seemed to be fulfilled. Paris and London, 297 miles apart, were enabled to converse with each other in April, 1891. New York and Cleveland were connected, though 650 miles apart, in 1883, and the superiority of the long distance telephone to the telegraph was clearly shown during the great blizzard of 1898, when for several days the only direct means of communication between Boston and New York was a long distance telephone wire, which withstood the storm that destroyed all other lines. Chicago was brought into communication with New York in October, 1892, and now conversation is carried on as easily over this distance of a thousand miles as if between two residents in the same city. This line has hundreds of branches to nearby points between the two great American metropolises. During 1898 the long distance telephone service was extended to

Austin, Tex., and it is possible for a person in that city to talk with Bangor, Me., a distance of 2,600 miles.

Novel applications of the telephone have made it possible for the invalid sitting at home to hear the sermon of a favorite preacher or the songs sung by a great songstress in a concert hall scores of miles away. Early in 1895 the rector of Christ Church, in Birmingham, England, attached several telephones to his writing desk, pulpit, organ and choir, and connected them with hospitals and jails in seven large cities at distances ranging from 100 to 250 miles. In all of these the whole service at Christ Church was heard simultaneously.

More than one practical method of sending several telephone messages at once over one and the same wire has been devised. W. W. Jacques, an American, and Hutin & Le Blanc, of France, have accomplished the feat of enabling a dozen pairs of persons to talk over one telephone, and by means of a single wire, so perfectly that the conversation of each pair does not in the least interfere with the conversation of any of the others. Part of the articulated utterance of one of the speakers is sent over the line, and before the rest of it goes over the wire the other eleven speakers have each had a turn in succession; this being possible because every sound occupying but the one hundred and five thousandth part of a second can be heard, while an interruption, lasting as long as the one-hundredth part of a second in a sound continuous, except for such interruption, cannot be detected.

Telephoning by a ray of light instead of wire, on the same principle as telephoning without wires, is the subject of present experiments by Professor Gray and Bell. It is said that this invention, known as the radiophone, is practically perfected, and is only awaiting a favorable opportunity for its official application. The

theory is that a ray of light may be impressed with sound vibrations in exactly the same manner that an electrically charged wire receives them from the telephone. The details of Professor Bell's invention have been kept a secret by him, but he has been able to transmit the human voice a distance of more than a mile and a half by its aid. As a commercial invention it has been retarded by the fact that an instrument which has to depend entirely upon sunlight for its efficiency might be least available when most necessary. Professor Bell declares, however, that he sees no reason why, if the right sort of light were found, it would not be possible to establish a series of reflecting mirrors at convenient distances apart, so as to reflect the ray in any desired direction, when it would only be necessary that there should be nothing in the way of an obstruction to cross the beam in its travels from mirror to mirror.

Improvements in shorthand have made possible more rapid communication. By its perfection during the latter part of the Nineteenth Century the extemporaneous speeches and addresses made by the master minds of the Century are taken down as delivered and preserved for the perusal of future ages. Had such a device existed in the time of Demosthenes what priceless gems of oratory would be preserved as models for orators. The Greeks and Romans had a system of shorthand, but it was crude. Isaac Pitman, in 1837, made such improvements in the systems in use in his day that he is called the father of modern shorthand. Charles Dickens, when he began the study of shorthand in 1824, adopted the best method then in existence, but was compelled to learn the use of more than 100 signs and symbols, many of which were arbitrary. Pitman reduced a number of these signs and simplified them so that to-day a stenographer's pencil can follow the most rapid orator. Single minute tests

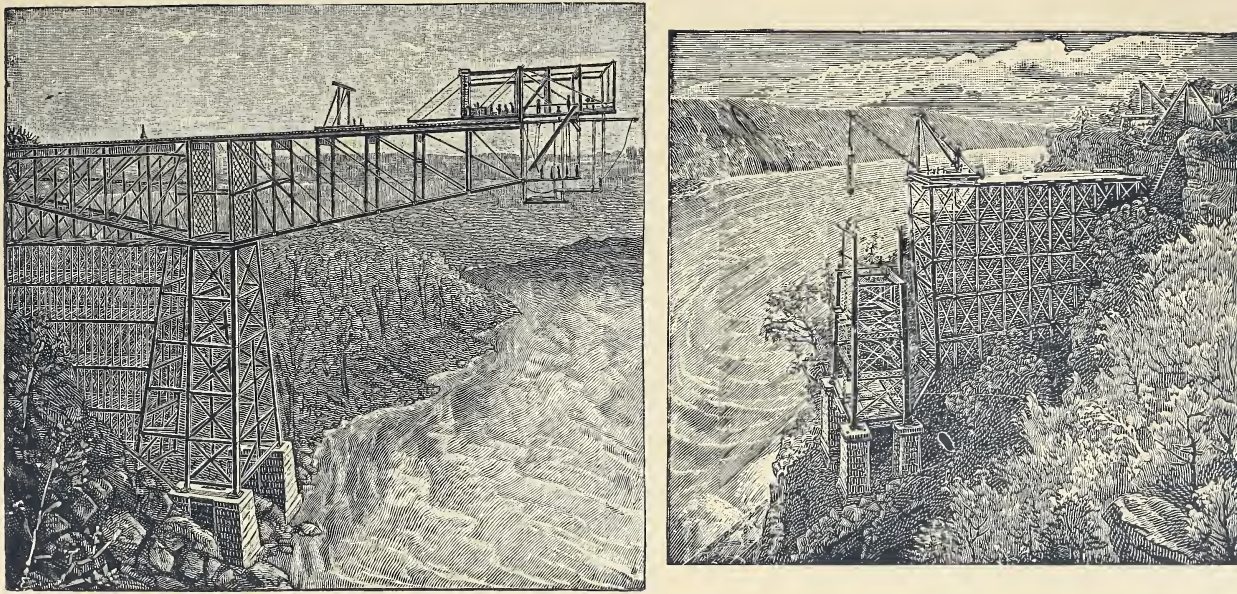
have been made, with faultless transcriptions, ranging as high as 407 words per minute, while writing new matter from continuous dictation 252 words per minute have been taken for five minutes. This record was made by Isaac S. Dement, of Chicago, at Lake George, N. Y., in 1888.

Simple as the typewriting machine of the present seems and as great a necessity as it is to the business man of to-day, it is a creature of but yesterday. One wonders how the people of a generation ago managed to transact business without it. Now the nimble fingers of the typewriter girl, flying swiftly over the keys, write many times as rapidly and in clear, distinct, legible characters the messages sent by business men to their correspondents. The author no longer "takes his pen in hand," but sits down before a typewriter that delivers copy, which saves the temper and eyesight of the compositor. It seems but a simple invention, yet how much time it saves to those who write and receive letters! Various attempts were made as early as 1675 to invent a machine that would print writing and answer the purposes of the modern typewriter. But none of these was successful, and no authentic description of such a machine remains. The first working model of the typewriter was exhibited by Folcault at the Paris Exposition in 1855. It was designed for the use of blind persons, and bore little resemblance to the machine now employed. The inventors, however, kept hammering at the idea of a practical machine, and several models along this line were perfected and patented in Europe and the United States.

The machine in its present perfected form may be said to date from 1873. The machines in present use are of three kinds—type-bar machines, cylinder machines, and wheel machines. In the type-bar machine,

which is the one most used, steel types are fixed at the extremity of a bar or rod of iron. By striking the key of any particular letter a lever is moved which raises the type-bar and causes the type at its point to strike on an ink ribbon and impress a letter on the paper, which is held against an India rubber roller. The type bars are so hinged that all the types when they are struck hit in precisely the same spot; so that if the paper remained stationary the impressions of all the type struck would be superimposed on each other. By automatic mechanism the cylinder under the paper moves a space to the left with the impression of each letter, and the depression of a wooden bar similarly moves the cylinder a space after each word.

Numerous improvements have been made, and there are now a host of excellent writing machines. The speed which can be attained is a matter of much controversy. A rate of 204 words has been attained on some of the leading machines in single minute tests, the operators writing from memorized sentences. A continuous speed of 100 words per minute is, however, the probable limit of an expert operator in actual work.



CANTILEVER BRIDGE, NIAGARA FALLS, AS IN COURSE OF CONSTRUCTION

For Michigan Central Railroad

ENGINEERING

"Give me a fulcrum on which to rest, and I will move the earth," said Archimedes when he discovered the lever. The modern engineer has found a standing point and he literally moves the earth—not, it is true, in its place among the stars, but in that he brings every part of the universe nearer to the other and bends the forces of nature to his own purposes. The progress of the science of engineering is shown by its specialization during the Century. Mining and electrical engineering are treated elsewhere. Here it is the intention to tell of the progress in civil engineering during one hundred years and also to trace the development of steam, gas, and water power by the mechanical engineer.

All industries are indebted to the engineer. Civil engineering ranks among the learned professions, and mechanical engineering has ceased to be classed as a trade. It is the engineer, that magician of the Nineteenth Century, who binds the world together with the steel rails of the railway and the electric wire of the telegraph. He builds mammoth machines which will crush a ton of granite or crack an egg with equal ease; he has made use of the secrets of the elements, and realizes the imagery of Job in that he measures the mountains and rides upon the whirlwind. Gleaning the theories and facts from the scientists, who ferret out the secrets of nature, he makes use of them for the benefit of industry. No problem daunts the engineer of to-day; no feat is so impossible that he is not ready to essay it. He annihilates space and matter. The spirit of the mountain and the demon of the

deep have not terrified him. The deepest valleys and the highest mountains are his playthings; he bridges the one and tunnels through the bowels of the other. He lifts great masses weighing thousands of tons with the ease with which a man will lift his finger. The feats fabled of the eastern genii are eclipsed by his everyday performances. "The high object of our profession is to consider and determine the most economic use of time, power, and matter," said a famous American engineer. That there will be further progress in this direction is certain, but it will be a marvelous Century that can show half so great a progress as has been made in that which is now closing.

To no industry has the engineer given a greater share of his art than to that of perfecting everything connected with railroading, and it is chiefly in the United States that this development has taken place. The steel rail as we know it to-day is in itself a wonderful piece of engineering. Thirty-five years ago the rail was of wrought-iron and shaped like a pear-head, but its evolution under the hands of the engineer has made it of steel and fitted it in every way for the work that it has to perform. Simple as it it, there is a reason for every curve, dimension and angle. It is made expressly for the purpose of sustaining its heavy loads and standing the impact of the countless blows it receives.

So, too, the location of the railroad and the determination of exactly where every foot of the track shall be laid is an engineering feat. In the early days it was thought impossible for a locomotive to climb grades. The engineer has found just what grades the locomotive will climb and locates his track accordingly. Tunnels and great rivers were supposed to present practically unsurmountable obstacles, but the patient work of the engineer

has shown that the greatest mountains might be pierced and the greatest chasms bridged. Railways can be built wherever it is profitable to build them.

Engineers of the olden time worked with stone, while those of to-day use steel. Fifty years ago bridges were built almost entirely of wood and stone. As long ago as 1779 the first iron bridge in England was built, and with 100-foot span and 370 tons of iron used in construction, it was the wonder of a generation, although it seems puny enough compared to the great Forth bridge of to-day, with 51,000 tons of steel. How conditions have changed since 1779 is shown by the fact that since 1870 it has been a law in Russia that no bridges shall be made of wood. Yet the Howe wooden truss bridge of 1840 was regarded as a wonder in its day, and some of them are still doing excellent service, the most famous being Wernberg's "Colossus," with 240 feet span over the Schuylkill.

Small streams were bridged at first and then the larger rivers were crossed, until now there is talk of bridging the English channel, making a railway journey possible from London to Paris, and the bridge would probably be built were it not that it would destroy the military advantages possessed by England through its insular position. In the United States alone there are now over 3,000 miles of bridgework, enough to form a highway across the Continent. This progress has been made possible by the use of iron and steel, the application of new theories of forces. The first attempt to use iron exclusively for long spans was the tubular bridge. Stephenson and Harrison had finished in 1849 the high-level bridge at Newcastle-on-Tyne. The first iron bridge in the United States was built at Frankfort, N. Y., in 1840.

By the introduction of the suspension bridge a great stride was made in bridge-building. Telford, a Scotch

engineer, designed the first bridge across the Menai Straits in 1818, and it was opened in 1826, with a span of 579 feet and a roadway 100 feet above the water level. Other suspension bridges followed of increasing size. The general principle of the suspension bridge is exemplified in a chain hanging between two fixed points on the same level. If two chains were placed parallel to each other a roadway for a bridge might be formed by laying planks across it, but the ascent and descent would be necessarily steep. No amount of force could stretch the chains perfectly level, as even a small piece of straight cord cannot be stretched horizontally in a perfectly straight line. It was a happy idea to hang the roadway from the chains, for then the roadway would remain perfectly level if built so as to be level after the curve had been figured. The suspension bridge built by Roebling in 1852 had a span of 800 feet. It was followed by the Clifton bridge, opened in 1864. The Clifton bridge at Niagara Falls, and the bridges at Pittsburg and Cincinnati are of this type. The largest of all is the Brooklyn bridge, erected at a cost of $15,500,000, and having a clear water-way of 1,595 1-2 feet. It was begun in 1870 and opened May 24, 1883. Each cable contains 5,296 parallel (not twisted) galvanized steel oil coated wire, closely wrapped into a solid cylinder 15 3-4 inches in diameter, and the permanent weight suspended from these gigantic cables is 14,680 tons.

The favorite form of bridge-building at present is the cantilever system, the first metal bridge of that type being Shaler Smith's cantilever over the Kentucky River, erected in 1877. The principle of the cantilever is very simple. A powerful structure of steel, in shape not unlike the walking-beam of a paddle steamer, rests upon a pier. The weight on one side balances that on the other,

but the arms of the two cantilevers do not meet. Imagine an engine's walking beam thirteen hundred feet long—almost a quarter of a mile—resting upon its center so that it projects in either direction 675 feet. Next fancy two such cantilevers so placed that their ends leave an abyss of 350 feet between them. This space is filled with an ordinary girder bridge, the ends of the two cantilevers serving as piers. The Forth bridge, built on this principle and opened in 1890, is the largest spanned bridge, having a length of 8,098 feet. It is composed of three double cantilevers; a central one of 1,620 feet resting on a pier built on the Island of Inchgarvie, two 1,514 feet in length joined to the central cantilever by girders of 350 feet span. The highest elevation of the bridge is 361 feet over the piers. Fifty-one thousand tons of steel were used in the construction of the bridge and fifty-six lives were lost during its erection, which occupied seven years and gave employment to as many as 5,000 men at one time. The total cost of this bridge, which is across the Firth of Forth at Queensbury, Scotland, was $16,000,000. The bridge at Memphis, Tenn., is the longest cantilever bridge in the United States, the greatest of its three spans being 720 feet.

Improvements in sinking the foundations have been nearly as great as those in raising the superstructure. The caisson is an application of the diving-bell that has simplified the work of sinking piers, and a German inventor has recently devised a process by which soft earth can be frozen and then dug out as if it were solid rock.

Modern engineering has made tunneling a comparatively simple operation. The tunnel is as old as the bridge, but its development has been no less remarkable. The early tunnels in the Century required the expenditure of an enormous amount of time, but new devices for rock-

boring and the removal of soft earth have simplified matters. One of the earliest known tunnels, said to have been constructed to drain the plateau on which stands the City of Mexico, pierced the Nochistengo ridge for six miles. It was destroyed during a flood and was replaced by an open cut in 1608. But it required more than a century to build that tunnel with the devices then in the possession of engineers. The work was done almost entirely by hand and although the workmen were paid only 9 cents a day, the cost was $6,000,000. Aside from the free workmen all convicts sentenced to hard labor were put to work on the tunnel, which cost the lives of more than 100,000 workmen.

Nowadays machinery has replaced hand labor to a great extent, and there is no such great sacrifice of men required. This has made possible the building of tunnels of great length. The machine rock drill, invented by J. J. Couch, an American, in 1849, was first used in tunneling Mont Cenis, and made possible the Hoosac tunnel. Mont Cenis tunnel was long one of the wonders of the world. Nearly eight miles in length, it extends from Madane to Bardonneche under the Col de Frejus. The work was begun in 1857, with rock-boring machines, but these proving impractical, for four years the workmen drilled holes and blasted the rock by manual labor. Improvements in the machinery invented by Couch then made possible the use of machinery. Before the machines were employed progress could be made at the rate of eighteen inches per day; towards the close, when the rock-boring machinery was in full working order, as much as 400 feet per month was excavated. From 1857 to 1860 by hand labor alone 1,646 meters were excavated; from 1861 to 1870 the remaining 10,587 meters were completed by machine.

Most remarkable of completed tunnels is the St. Gothard, piercing the Alps. Work was begun in September, 1872, at each end, and it is a remarkable feat of civil engineering that the two openings met, in spite of the difficulty of the survey, with a variation of only 2 inches horizontally and 13 inches laterally. The tunnel is 9 1-2 miles long and cost about $700 per lineal yard. The first passenger train ran through the tunnel on November 1, 1881, thus making possible the passing of the Alps at a point where before it had been possible only to mountaineers. Hannibal himself could not have led an army over the Alps at that point. The motive power of the rock-drilling machines was actuated, as was the case with the Mont Cenis tunnel, by compressed air, and the power used for compressing the air was a head of water.

The Simplon tunnel, though begun in this Century, will not be completed until the next. It will supersede the Simplon Pass road, begun in 1800 by Napoleon, who wished a military road to Italy and built it in six years, at an expenditure of $4,000,000 and the loss of innumerable lives. The Simplon tunnel will be 12 1-4 miles long, making it the longest in the world. Brandt rotary hydraulic drilling machines are to be used, and the pressure will be from 1,000 to 1,500 pounds to the square inch. Six or eight machines will be used at each heading. The Brandt machine has three cutting points like claws, with a lightly rotary movement, and works by hydraulic pressure.

The rock-boring machine known as the Burleigh, perfected in 1837, gave a great impetus to tunneling. It looks like a big syringe, supported upon a tripod, and is worked by compressed air. It eats holes two inches in diameter in solid granite, and makes honeycomb of it as easily as a schoolboy would demolish a small sponge cake. It pounds away at the rate of 200 strokes a minute, in

which time it progresses forward about twelve inches, keeping the holes free of the pounded rock. The principal feature of the machine is that it imitates in every way the action of the quarryman in boring a rock. Another type of rock-boring machine is the diamond drill, which surpasses all others in the rapidity with which it eats its way through solid rock.

Rock-boring is comparatively easy nowadays. When soft material is encountered the work is more difficult, it being necessary to keep the material from clogging the excavation already made. A device has been invented to overcome this, and it was used in the railroad tunnel under the St. Clair River at Port Huron. It is called a shield, and is generally used in cities for smaller tunnels. In the St. Clair tunnel a great cylinder weighing more than 60 tons, 20 feet in diameter, and 16 feet long, was driven into the blue clay, which constituted the entire bottom of the river, with as great ease as cakes of soap can be carved out of a general mass. Inside this "shield" twenty-two men worked removing the dirt. As fast as the shield was pushed forward, which was 2 feet at a time, the clay thus brought inside was dug out to the end of the cylinder. Then the hydraulic jacks were again started and slowly but irresistibly the immense iron tube moved another two feet into the solid earth ahead of it. Each jack had a power of 3,000 tons and the combined power behind the shield was more than 400,000 tons.

When water floods the work there is great risk. It was necessary to pump 2,000 gallons of water a minute to prevent the flooding of the Kilsby tunnel, and in the construction of the Severn tunnel in England (1873-85), which has a length of 4 1-3 miles, the tunnel was flooded for a year by the tapping of a large spring, and

the erection of permanent pumping engines was made necessary.

The canals of the Century are not the greatest in length. There is one in China nearly 700 miles long, the longest in the world, that dates back to the Thirteenth Century. The era of canal opening in the United States began early, and the Erie canal running from Albany to Buffalo is 351.8 miles in length, and was opened in 1825. But these canal enterprises have been dwarfed as engineering enterprises and in importance by the Suez canal, which is regarded by many as the greatest engineering feat of the world. While the ancient Egyptians did not cut directly through the isthmus, Herodotus describes a canal from Suez to the Nile, but it became clogged with sand, and until DeLesseps dug his great ditch it was regarded as necessary for all ships to make the journey around Africa to reach the Indies. The isthmus made necessary a journey of 15,000 miles, and a glance at the map of Africa will show the enormous saving in time which it effects. The journey around Africa was so great that it was to avoid this that Columbus, ignorant of the size of the world, made his journey westward that led to the discovery of America.

The story of the canal is a thrilling romance. It was conceived by DeLesseps in 1834, twenty years before he got his concession. Then followed intrigues and diplomacy with Turkey and foreign powers before he could get permission to work. Then it became necessary to raise the enormous capital of $92,000,000 which it cost. In spite of the obstacles the objections were finally overcome and the canal built, being opened in November, 1869.

The Suez canal is 88 geographical or about 100 statute miles long. The engineering difficulties were enormous.

The minimum depth is 26 feet, and this was necessary because of the size of the vessels which would use it. Its average width is 25 yards. It had to be dug through sand, and it was made possible only by the invention of dredges to do the work. But for these the canal would never have been built through the sand. These dredges were the contrivance of one of the contractors. The use of the dredging machines was prepared for by digging out a rough trough by spade work and as soon as it had been dug to the depth of from six to twelve feet, the water was let in. After the water was let in the steam dredges were floated down the stream, moored against the bank and set to work. There were two kinds of dredges. One, known as couloir, was a large barge of wood supporting an endless chain of heavy iron buckets which scooped up the mud and sand which was discharged through pipes onto the embankment. Smaller movable dredges were also used which discharged the mud and sand on barges, which were divided into compartments fixed on trucks, and, raised by steam, were placed on an inclined plane that carried the mud to the shore. Many were the problems of engineering which were solved during the construction of the canal.

Another great canal is the one connecting the North Sea and the Baltic, running from the mouth of the Elbe to the gulf of Kiel. Begun in 1887, it was opened in 1895. It is 60 miles long and has a depth of 28 feet and a width of 197 feet, being sufficient to float the largest vessels of the German navy. The working plant consisted of ninety locomotives, 2,473 cars, 133 lighters, 55 steam-engines, and 8,600 men. The Manchester canal, which has made Manchester a seaport, is another great canal enterprise of the Century. Thirty-five and a half

miles in length, it was opened in 1893, and has a depth of 26 feet and a width of 172 feet.

By the use of shields and dredges the engineers have sunk great piers, effected wonders in sanitary engineering, built sewers and jetties, using marvelous machinery, often invented expressly for the purpose. The levees built along the banks of the Mississippi and other rivers have been triumphs of engineering skill, and have saved thousands of lives from floods, although the loss of life is still great.

By the skill of the engineer, aided by the architect, tall buildings, rivaling the tower of Babel, rear their heads skyward in the great cities. Buildings of eighteen and twenty stories have ceased to be uncommon. They have been made necessary by the congestion of the great cities, for when from $150 to $300 a square foot is paid for land it is necessary to build tall structures in order to pay interest on the ground and the cost of the building. There was a limit beyond which structures of brick and wood might be built, but the use of iron and steel made it possible to build taller structures, two or three times the height of those possible by the old method. The new method of construction known as the skeleton frame construction, does away with the use of brick and masonry except as a thin shell. Steel beams support the walls of each story and these are framed between columns, permitting thin walls even at the base. The frame work of iron and steel being erected, the masons and carpenters can work on all floors at once and build from top and bottom. Great as have been the improvements in construction, the erection of these buildings calls for the highest engineering skill. The Manhattan Life building in New York, which is twenty-three stories high, weighs 21,000 tons, and there is a pressure of wind estimated at

2,400 tons against its exposed sides, while the total weight, including tenants and furniture, is not far from 31,000 tons. It is necessary to so construct these buildings that the settling from the weight may be accurately estimated. A twenty-story structure will have sixteen elevators that will travel 120,000 miles in a year on 14 miles of wire ropes. From 30 to 50 miles of electrical wire serve to light the building and supply telephone connections for the two or three thousand people who live in the great edifices, while miles upon miles of steam pipes supply the tenants with water. In such buildings one may attend to every want without budging from them, there being post-office, express offices, telegraph offices, and other such conveniences, as well as restaurants and every kind of shop, except, perhaps, livery stables and feed-stores.

It is difficult to foretell the future of the construction of such buildings, but it is predicted that within a score of years they may reach thirty and forty stories in height.

Two of the most interesting pieces of engineering of the Century are the Eiffel tower and the Ferris wheel. The first, erected in 1889 as the crowning glory of the Paris Exposition and a triumph of French skill, was the idea of Gustave Eiffel. It is 985 feet high, contains 7,300 tons of iron, and cost $1,000,000. The appearance of the Eiffel tower is familiar to every one, and it is scarcely possible to convey any adequate idea of the great network of bracings by which each standard of the columns is united to form the loftiest structure in the world.

The engineering feat of the World's Columbian Exposition held at Chicago was the Ferris wheel, the invention of G. W. G. Ferris, of Pittsburg. It is an enormous "merry-go-round," as the machine at country fairs is called, and the novelty consisted in its magnitude, which

called for the highest engineering skill. The great wheel is 250 feet in diameter, and to its periphery were hung thirty-six carriages, each seating forty persons. At each revolution 1,440 people may be raised into the air and from that elevation afforded a splendid prospect, besides an experience of the peculiar sensation, like that of being in a balloon, when the spectator has no perception of his motion, but the objects beneath him appear to have the contrary motion; that is to say they seem to be sinking when he is rising and vice versa. Begun in March, 1893, the structure was completed in three months at a cost of $325,000.

Though the steam-engine itself is an invention of the previous Century, its application to everything under the sun is an achievement of the Nineteenth Century. The Century has also been remarkable for the attempts to get the greatest possible return from the fuel employed with the least possible waste, which followed the general recognition of the principle of the conservation of energy—allusion to which is made in another part of this volume. The energy stored up in coal is converted into heat energy in the process of combustion, and transferred with various losses to steam. This is made by suitable engines to yield up some proportion of its heat energy for conversion into mechanical motion. More energy than the coal supplies it is impossible to obtain as energy of motion, and engineers with a clear realization of this principle have abandoned all schemes for the solution of the perpetual motion problem. The criticism of an engine is therefore on the returns which it yields for the expenditure of fuel. The inventions of the Century have been in the direction of the elimination of friction from the working parts and the employment of methods of construction that give greater power for a small total weight.

As Watt in the last Century found the steam engine an imperfect and wasteful arrangement for utilizing only a small portion of the energy of the steam supplied to it and by the invention of his condenser and then by making the engine double acting, made it really a steam engine; so a great step forward was taken by Woolf in 1804, when he developed the compound engine from the crude ideas of Hornblower of 1781. Using steam of fairly high pressure Woolf expanded it to several times its original volume by cutting off the supply before the end of the stroke in a small cylinder. Its chief advantage is that it limits to a great extent the waste which results from the heating and cooling of the metal by contact with hot and cooler steam. This is the greatest improvement in the steam engine since the time of Watt, but its advantage was not recognized until about the middle of the Century, when the discoveries of McNaught in 1845 and of Cowper in 1857, made possible the use of high-pressure steam, and compound expansion became more and more general. In marine engineering, where economy of fuel is of greatest importance, we find triple and even quadruple expansion engines, while the idea is recognized even in the locomotive engines of to-day. The first triple-expansion engine was made by Kirk in 1874.

In other directions the progress of the steam-engine has been in features of mechanical detail and its growing application to nearly every use.

The higher pressure of engines gave rise to a new problem, that of the strength of boiler, cylinders, and accessory connections necessary to withstand the enormous internal pressure of the steam. Improved quality of adaptability of iron and steel have made this possible, and steam boilers step by step have developed to their present form. Manual labor was used almost exclusively

in this work until 1885, the boilers being of wrought iron and riveted by hand. Mild steel boiler plates and machine riveting have to a great extent succeeded these, although, in spite of the fact that hand-riveting is much slower, there are those who contend that it is better.

During the last few years the tubulous boiler has been introduced. This is made so that it has no large internal space and can thus be used for heat at high temperatures. It more nearly approaches the theory of Sadi-Carnot, evolved in 1824, which is that the efficiency of any heat engine has its maximum limit fixed by the range of temperature employed with the working substance.

Gas and petroleum engines have gained their development during this Century. Street's engine in 1794 was on the principle of internal combustion, to which they owe their origin, and was worked by the combustion of vaporized oil and turpentine. In engines of this type the working substance is heated by its own combustion in the motor cylinder, and because of the greater range of temperature employed they are of higher efficiency. The water jacket introduced by Brown in 1823, to keep the cylinder cool and prevent the rapid degradation due to heat, and the improvements of Lenoir have made them practicable. The Otto gas engine, introduced in 1863, was noisy and mechanically defective, but the Otto silent of 1876 has proved a powerful rival to small steam-engines. Air sufficient for combustion is mixed with gas and a temperature of about 1,600 centigrade, with a pressure of 100 pounds per square inch is obtained, with the expenditure of only twenty-four cubic feet of gas per horse power per hour. This is more economical than any small steam engine. But with larger engines the advantage is with the coal engine, except where natural gas is used. Gas is used in engines just as it is used in

grates, stoves, and ranges, always on a comparatively small scale, where the high price is offset by cleanliness and convenience. A gas engine means only the turning on of a stop-cock and it comes to full speed in a minute or two and hence where small power is used or the large power is intermittent, the gas-engine is most economical.

Petroleum and gasoline engines, which have been successfully applied to horseless carriages, being the favorite method of propulsion for these vehicles—work on the same principle as the gas engine. Instead of the simple admission of gas a sprayed jet of oil is broken up by compressed air playing on it in a nozzle. It is then further heated and fully vaporized by the hot products of the exhaust. The chief objection to the oil engine is its odor.

During the last half Century the improvements in steam-power have increased its use nearly fifty-fold. The growth of the use of steam has been from an effective horse power of 1,650,000,000 tons horse power in 1840 to 9,850,000,000 in 1860 to 55,580,000,000 horse power in 1895, according to Mulhall's estimates. Of this total steam power, the United States and Great Britain together possess more than half that of the world, the horse power of the engines of the United States being 16,940,000,000 and that of the British engines 12,970,000,000.

An interesting and important illustration of the economy in the application of steam-power to mechanical contrivances is the steam-hammer. Large forge hammers had been in use actuated by steam before Nasmyth's invention in 1842, but they were worked in an indirect manner, the hammer having been lifted by cams and other expedients, which rendered the apparatus cumbersome, costly, and wasteful of power on account of the indirect way in which the original source of the force—namely,

the pressure of steam—had to reach its point of application by giving its blow to the hammer. The range of the fall of the hammer being only eighteen inches, there was a rapid decrease in the energy of blow in proportion to the size of the piece of iron. There was no means of controlling the force of the blow. Nasmyth hit upon the idea, when he received an order for the forging of a shaft for the paddle wheels of a steamer, the shaft to be three feet in diameter, a greater size than could be accommodated in any forge hammer in England. In a few minutes he hit upon the idea which has done more to revolutionize the manufacture of iron and steel than any other inventions that could be named, excepting those of Cort and Bessemer. For four years the hammer was not used outside of his shop, although now it is an absolute necessity in every engineering workshop. Owing to its vast range of power forged iron-work, by its means, can now be executed with a perfection not previously possible. Anything can be done with it, for the strength of the blow is regulated at will and the most minute details of machinery as well as the most gigantic parts are forged with its aid. At Woolwich arsenal there is a steam hammer, built in 1874, the falling portion of which weighs forty tons and which can strike a blow with a force of ninety-one tons.

The main feature of the steam-hammer is the direct manner by which the elastic power of steam is employed to lift up and let fall the mass of iron constituting the hammer, which is attached direct to the end of a piston-rod passing through the bottom of an inverted steam cylinder placed directly over the anvil. The steam is admitted below the piston, which is thus raised to any required height within the limits of the stroke. When the communication with the boiler is shut off and the

steam below the piston is allowed to escape, the piston with the mass of iron forming the hammer attached to the piston-rod falls by its own weight. This weight in large steam-hammers amounts to several tons, and the force of the blow will depend jointly upon the weight of the hammer and upon the height from which it is allowed to fall. The steam is admitted and allowed to escape by valves moved by a lever under the control of the workman. By allowing the hammer to be raised to a greater or less height, and by regulating the escape of the steam from beneath the piston, the operator has it in his power to vary the force of the blow. Men who are accustomed to this tool exhibit their perfect control with such accuracy that a watch may be placed face upwards on the anvil and a moistened wafer on it. The hammer will descend and pick up the wafer without cracking the crystal. Yet it may be a hammer capable of striking a blow of eighty tons.

Water-power has been used for thousands of years as a motive power, but its practical development has come within the last Century. The utilization of the vast forces has been greater, especially since water-power has been used as means for the furnishing of electricity, yet at the present time not 5 per cent of the water-power of the world has been rendered available for use, and the great Niagara Falls was not made to work until the last decade of the Nineteenth Century. While the modern turbine is the evolution of ages the principal developments were made during this century. J. Fourneyron in 1827 and St. Blasien in 1837 made great improvements, but in 1855 A. M. Swain, a mechanic who had been employed at the Lowell machine shop, conceived an idea which is the prototype of all the modern turbines; by combining the inward and downward flow wheels, curv-

ing the buckets both laterally and vertically he increased the efficiency of the water-wheel by 50 per cent. The gradual improvements since the time of Fourneyron in 1827 have served to furnish turbines of equal power in one-half the space and at one-fifth the cost, an enormous economy of power. The cumbersome mechanism required to use the water of a high fall has been replaced by simple mechanism that makes use of a small fall. Of water as a means of the generation of electricity allusion will be made in the story of miscellaneous electrical achievements.

MARVELOUS MACHINERY

The discovery of steam as a motive power and its application to the ingenious machinery of the age has effected the most rapid revolution of human affairs which the world has yet seen. Whatever may be the achievements of the future the Nineteenth Century will have a distinct and honorable place in history as the first age to devote its inventive thought to the lifting of labor's yoke from the toiler's neck. So successful has been the attempt that the optimist, peering into the dim, distant future, already sees a glimpse of Utopia. And, indeed, the most obdurate pessimist is forced to acknowledge that labor-saving machinery is bound sooner or later to annul the curse pronounced upon the human race—that by the sweat of his brow shall man eat his bread.

The effect of machinery upon labor and production is a problem too great for the finite intellect comprehensively to grasp. The magnitude of figures showing the development of machine production within the present generation is as interesting as it is bewildering. The productive power of the world has been multiplied many times, and several of these multiplications in important branches of production have occurred within the last decade. It is computed that the power capable of being exerted by the steam machinery of the world, in existence now, is equivalent to that of 1,000,000,000 men; or three times the working population of the earth, on the basis of the probable total population of the earth being about 1,460,000,000. Thus the application and use of steam alone up to the present time has more than trebled man's

working power. By enabling him to economize his physical strength, machinery has given him comparative leisure, comfort, and abundance, with greater opportunity for the mental training essential to the higher development of his species.

There is a constant multiplication of labor-saving machines. Patents are being applied for and issued daily on mechanical constructions designed either to aid or supplant man-power. There is no field of industry, however unimportant, which has not been invaded by the inventor with a view to minimizing the human effort required therein to produce its quota of material.

The sewing machine is probably the most familiar as well as one of the most important of labor-saving devices. Its value as a labor saver is incalculable when one considers that in the United States alone there are 700,000 manufactured annually. America is the sewing machine center of the world. The tenth day of September, 1846, may justly be considered the birthday of the sewing machine—that is the machine as we know it to-day. On that date Elias Howe, to whom has been accorded the title of father of the sewing machine, took out patents on a practical invention, to which have been constantly added improvements, until there now seems nothing lacking to its perfection. It is a remarkable fact that notwithstanding the sewing machine's being originally the idea of an Englishman, Americans, and Americans alone, have developed that idea. The records of the English Patent Office show that Thomas Saint patented a sewing machine in the latter part of the last Century. A clumsy and archaic device was this initial effort as compared with the beautiful mechanism of the modern machine. Saint's machine sewed with a chain stitch, an awl forming the hole, and a needle with a notch in its pointed end carried

the thread through the cloth and formed a loop. An equally crude attempt was made by Thimonnier, a Frenchman, in 1830. Walter Hunt, of New York, invented a machine in 1834, but his application for patent was rejected on the ground of abandonment.

Howe's struggle against adversity while perfecting the priceless secret which lay hidden in his brain, and his final triumph, read like a page of romance. When the father of the sewing machine first conceived the idea of his invention he was absolutely ignorant of the early attempts of his predecessors. Had he known of the attempts of Saint and Thimonnier his road to success might have been many years shorter. Howe's first device was a needle pointed at both ends, and having an eye in the center. He soon abandoned this idea. Then there came to him the happy thought, all his own, of using two separate threads, one in the needle and the other under the cloth, and forming a stitch by the co-operation of the shuttle. This was in 1844, and in 1845 he had constructed a machine along these lines, on which he sewed two complete suits of clothes for himself. Flushed with triumph, the inventor submitted his machine to the inspection of the tailors, to be met not with encouragement, but with suspicion and derision, although the machine beat five of the swiftest sewers. After securing his patent, Howe, discouraged by the treatment which his countrymen had accorded him, betook himself to London with his "hobby." Here he fared no better, and several years later returned to America, penniless, to discover that in his absence the mechanical world had awakened to its possibilities and that his shuttle machine was being built and sold right and left. After a bitter contest, Howe was given the custody and control of the child of his brain. In pronouncing the verdict in Howe's suit

against I. M. Singer & Company, decreed in 1854, Judge Sprague, of Massachussets, observed that "there is no evidence in this case that leaves the shadow of a doubt that, for all the benefit bestowed upon the public by the introduction of the sewing machine, the public are indebted to Mr. Howe." Howe realized during his life more than a million dollars in royalties and license fees for his inventions and improvements, and Isaac M. Singer lived to see the business, of which he was the founder, develop into colossal proportions from the investment of $40. Howe was decorated with the cross of the Legion of Honor by France in 1867, the year of his death.

Next to Howe, Allen B. Wilson is the inventor who has done most to give us the present perfected machine. The two most ingenious and beautiful pieces of mechanism, the rotating hook and four-motion feed, are his inventions. He claims to have conceived the idea of a sewing machine in 1847. In 1851 Wilson patented his famous rotating hook. This performs the functions of a shuttle by catching the upper thread and drawing its loop over a circular bobbin containing the under thread. The four-motion feed was added to the sewing machine in 1852, and like the rotating hook, was an invaluable adjunct. The four-motion feed, in combination with a spring presser foot, forms the basis of all modern feeding mechanisms. The feed bar had four distinct motions, two vertical and two horizontal. It is due to the reciprocal action of this mechanism that the cloth moves automatically along the seam, without the aid of the seamstress' hand. After securing patents on his improvements Wilson became acquainted with Nathaniel Wheeler, who possessed some capital, and out of this connection grew the firm of Wheeler & Wilson, who brought the sewing machine to a still higher degree of

perfection. The earlier machines had no driving power except the common hand crank. Isaac Singer conceived the idea of using a treadle similar to that employed on the old spinning wheel. Soon after came the iron treadle for both feet.

The sewing machine as originally invented was built with the sole purpose of cloth sewing. In 1851 Isaac Singer built a machine, patterned after the instrument in use in that day, but heavier and more powerful. This was designed for the leather industry, and indeed has completely revolutionized that branch of production, as will be shown farther on. Some idea of the patient investigation, deep thought, time and money that have been spent in perfecting the modern sewing machine may be gained from the fact that from 1842 to 1898 more than 7,000 patents have been granted on its various improvements and modifications.

It is in the use of sewing machines in factories that the greatest revolution has been effected. The manufactures in which sewing machines are essential are awnings, tents, sails, bags, bookbinding, boots and shoes, clothing for men and women, corsets, flags, banners, men's furnishing goods, gloves, mittens, hats, caps, pocketbooks, rubber and elastic goods, shirts, saddlery, and harness. The largest sewing machine in the world is in operation in Leeds. It weighs 6,500 pounds and sews cotton belting. One of the most beneficial effects of the sewing machine, next in importance to its value as a labor saver, is the cheapening of clothing. The enormous increase during the last ten years in the factory production of ready-made clothing has been coincident with and largely the result of the invention of special appliances and attachments adapting the sewing machine to factory operation in the performance of all stitching processes, in-

cluding button hole and eyelet making, attaching buttons, staying seams, inserting whalebone, etc., etc.

The concentration of the manufacture of clothing into factory operation, alone made possible by the sewing machine, has effected some important economics in the marketing of cloths, especially the cheaper fabrics, such as jeans, denims and shirtings. These goods are now sent directly to the mills, to the factory, and no longer pass through the jobber's hands. The extent to which wearing apparel of all kinds has been cheapened in consequence of the use of the sewing machine can be expressed only in figures running far up into the hundreds of millions. In the whole field of invention it is doubtful whether there has ever been devised such a great labor saver, or one that has ministered more intimately to the needs of the human race than the sewing machine.

No branch of industry has received a greater impetus by the introduction of labor-saving machinery than has the manufacture of boots and shoes. The cobbler and the journeyman shoemaker have become as obsolete as the spinning wheel and the distaff. Changes in shoemaking methods and processes have been most radical and rapid. Indeed the metamorphosis of the industry has occurred entirely in the past forty years. This great revolution is due to the sewing machine more than to any other mechanical factor. Formerly the fitting of the uppers was accomplished by sending them out in small quantities to be stitched by hand in the homes of the operatives. Then the sewing machine of a style and pattern adapted to the purpose was introduced into the factories, and steam power employed for the driving of the machines. In 1861 the first machine for sewing on soles was put into operation, and a royalty of 2 cents on each pair of shoes was exacted by the patentee. In one day of ten

hours 900 pairs of shoes could be sewed on one machine. The machine now in general use does its work in a manner closely resembling hand sewing. After examining the sewing and welting machine Thomas A. Edison declared it to be equaled only by the Blanchard lathe in ingenuity and importance. With the exception of the in-seam the whole of the sewing on even the finest pair of shoes is done by machinery, and the cheaper grades are made entirely by machine. A shoe factory in Lynn, Mass., made a pair of ladies' boots for the Paris Exposition of 1889 in just twenty-four minutes. For this feat the pair of shoes went through the usual routine of the shop. Forty-two machines and fifty-seven different operators contributed to the operation, which, included the cutting up and stitching of twenty-six pieces of leather, and fourteen pieces of cloth, the sewing on of twenty-four buttons, the working of twenty-four button holes, and the insertion of eighty tacks, twenty nails, and two steel shanks. Since that time still more perfect machinery has been introduced into the industry, and a pair of ladies' shoes may now be turned out in twenty minutes. It has been computed that the introduction of new machinery within the past thirty years has displaced employes in the proportion of six to one, and that the cost of the product has been reduced one-half. By the use of the Goodyear sewing machine, designed for turned shoes, one person can sew 250 pairs per day. Were the work to be done by hand it would require eight men to do the same amount of work in the same time. The heel shaver or trimmer enables one man to trim three hundred pairs a day, while formerly three men were required to do an equal amount of work in the same time. One operator can handle with the McKay

machine three hundred pairs of shoes per day where he formerly handled but five.

The evolution of the textile industry has been as rapid as it is picturesque. It is almost impossible to associate the whirr of the spinning wheel of the olden time with the terrific roar of the modern textile factory, and yet less than a hundred years ago the spinning wheel was found in the house of every thrifty man or woman. The labor saving machines which have contributed to make the industry what it is to-day have all been the inventions of the past fifty years. Before then the various processes of manufacture were in a transitory state of existence. In 1851 mechanical methods, systems and comparative perfections of product became known to the world at the London international exhibit, and from that time down to the present there has been a succession of clever inventions the ultimate object of which was the saving of human labor. No manufacture offers a more striking illustration of this apparent displacement of man by machine. With the power loom the weaver now weaves 180 picks per minute, whereas with the old hand loom he could weave but sixty. When the power loom was first introduced one weaver was required for each loom, and still more recent improvements have made it possible for one operative to attend to ten looms. The ring frame improvements in the spinning process have displaced that line of labor to such an extent that but one-third the number of operatives formerly required is now necessary. With the single spindle hand wheel one spinner could spin five skeins of number 32 twist in fifty-six hours. The modern mule spinning machine, containing 2,124 spindles, produces, with the assistance of one operator and two small girls, 55,098 skeins of the same thread in the same time. With the old hand loom one weaver could weave 42 yards of

coarse cotton per week; now a single operator can turn out 3,000 yards of the same product in the same time. It is computed that in the manufacture of cotton goods alone improved machinery has reduced muscular labor 50 per cent in the production of the same quality of goods.

So perfect is the equipment of the modern cotton factory, throughout, that the first processes through which a bale of cotton must pass are almost entirely automatic. The bale is broken open by machinery, thrown upon an endless chain, which carries it up through the mill and breaks and picks it to pieces. It then passes through machines that take out the dirt, and is run through great rollers, which separate the strands, and joins them together again almost in the form of yarn. It then passes into a machine which converts the soft mass into what resembles cotton batting, whence it goes to the carding machine. This mechanism contains teeth so fine that thousands of them are on a square foot of surface. These brush and comb the cotton as it passes through them, and turn it out in a great soft, white rope, which is seized by a series of machines which twist it tighter and tighter as it passes from one to another until it has been drawn out to the required fineness. It is now ready for the weaving room, and in five minutes the soulless machine has done an amount of work which would require the old time spinner long years of patient, unceasing toil. The thread comes to the weaving room wound on spindles, and another set of threads are wound upon rollers of the width of the cloth. These are to make the warp of the cloth. The spindles which move in and out with beautiful precision form the warp. The only human agency required in the actual process of weaving a piece of cotton is a girl or man to attend the loom and keep an eye on the shuttle, which flies back and forth about 150 times every minute. So

great has been the improvement of modern machinery over that used fifty years ago that the productive capacity of a spindle to-day is 44 per cent greater than it was then, and the industry itself has increased in production almost 900 per cent.

What is true of the cotton manufacture is likewise so of the wool-weaving industry. Improvements in machinery and labor-saving methods have expanded the annual product from $70,000,000 in 1850, to nearly $300,000,000. The chief mechanical factors responsible for this vast increase are the loom and the comb, now brought to a remarkable state of efficiency. The combing machine which is almost identical to that used in cotton making, is of comparative recent development. The introduction of the improved machine about seventeen years ago completely revolutionized the wool industry, with a consequent increase in productiveness of about $100,000,000 and a proportionately infinite decrease of labor.

The inventive genius of mankind has not despised the plebeian, but useful, nail, and labor-saving mechanisms for its output are so successful that the cost of production of a single keg of nails is infinitisimal. Indeed so cheap have wire nails become that if a carpenter drops one it is cheaper for him to let it lie than to stop and pick it up. It is claimed that one keg out of five is never used, but goes to waste. A statistician who recently figured this out, on the assumption that it takes a carpenter ten second to pick up a nail, and his time is worth thirty cents an hour, computes that the recovery of the dropped nail would cost 0.083 cent; while the cost of an individual sixpenny nail is 0.0077. Such a calculation brings out clearly the marvelous reduction in prices due to inventive genius. This is true of every item which would come under the cover of a hardware dealer's catalogue. There are in machine

shops all over the country gray-haired mechanics who well remember the time when the ideas of machine-made files were held up to scorn, and when all first-class, well-known makes of files were hand cut. It would be difficult for them to now tell the difference between a hand-made and a machine-made file. Within the past few years machines have been making files which cannot be approached by the most expert file cutters of Sheffield. The great difficulty in perfecting the file-cutting machine was the inability to cut uneven teeth, for the teeth of a file are not so even as they look. This irregularity in the case of hand-made files, was the evidence of extraordinary skill, and it was on this point that the hand workers considered their position unassailable. The successful machine cuts the teeth with a loose chisel, and the feed is such that the gradation of width and depth gives the teeth that unevenness so desirable. Equally incredulous were the old-school mechanics over the possibilities of the machine-made rasp, which late years have seen brought to a high state of mechanical perfection.

Pins, like nails, are such a cheap commodity that it is an extravagant waste of time to pick up a dropped one from the floor. And yet not so very long ago it took twelve to fourteen men to make a pin—that is, there were twelve or fourteen processes in its manufacture, each requiring performance separately and by a different hand. Now one machine turns out a steady stream of pins at the rate of more than two hundred a minute. Until the present Century, particularly the latter half of it, pins have been esteemed almost as dearly as jewels and fine laces. The term, "pin money," is significant of the value attached to the article. One of the laws of the ancient pin-makers of Paris was that no maker should open more than one shop for the sale of his ware, except on New Year's Eve

and New Year's Day. Then the court ladies obtained money from their husbands and rushed to the pin shops to lay in their yearly supply. Even so late as 1761 John and Thomas Stevenson inserted a modest advertisement in a Boston newspaper informing their customers that among other elegancies they had imported pins and needles.

Simple and insignificant as is the pin in appearance, its manufacture involves a most complicated process, and much intelligent thought and ingenuity has been expended upon the perfection of mechanism that contributes to its immense production. The wire is prepared by drawing it from an immense coil through an aperture the size of the pin wanted. It then passes into a machine through a hole and between a series of iron pegs, which straighten it and hold it in place. A pair of pincers pulls it along and thrusts the end of the wire through a hole in an iron plate, on the other side of which a little hammer beats on the end of the wire and thus forms the head of the pin. Then a knife descends and cuts it off to the required length. The pin falls into a groove, from which it hangs suspended by the head and with the lower end exposed to the action of a cylinder by which process the pin is pointed. These processes are all performed with such rapidity that there is an endless stream of them falling from the end of the machine. They next pass between two grinding wheels and are forced against a rapidly moving band faced with emery cloth, which gives them a still sharper point. After they are dipped in the polishing tub of oil, where they receive a brilliant polish and finish, they are ready for the sticker, where they fall from a hopper on an inclined plane containing a number of slits. The pins are caught in these slits, point downward, and slide along to an apparatus which inserts them in paper. This mechanism is perhaps the most beautiful and ingenious of all the complicated con-

trivances that help in the making and manipulation of the pin. It does its work at the rate of 100,000 pins an hour, and yet so delicate is its constructions that a single bent or imperfect pin will cause it to stop feeding until the obstruction is removed by the attendant. The pin factories of the United States, forty-five in number, employ 1,600 persons, and turn out pins to the value of $1,000,000 annually. By a computation made in London ten years ago it was shown that the weekly production of pins in Great Britain alone was 280,000,000, of which considerably more than half were made in Birmingham. At that time 120,000,000 per week were made in France, and another 120,000,000 in Germany, Holland and Belgium. Since then the production of pins has increased largely. It is calculated that only 1 per cent of the pins manufactured are worn out or broken. The other 99 per cent are lost.

The needle, though old as civilization itself, had to wait until the Nineteenth Century to see its most perfect and economical development. Until 1826, when a machine for producing drill-eye needles was introduced, they were made almost entirely by hand. The first mills, established early in the last Century, were utilized for scouring and pointing needles, displacing the process of wrapping in emery dust and olive oil and the two days rolling, which was but a small part of the elaborate manual process which every needle had to go through prior to that time. The making of a needle by hand was quite as tedious an undertaking as would be the search for one lost in a haystack. Small square rods of steel were passed through a charcoal fire and wrought into cylindrical form by a hammer. The rod, reheated, was thrust through a large hole in a wire drawing iron. This heating process was repeated over and over again, each time the rod being forced through a smaller

hole than the preceding, until the steel bar was reduced to the small diameter required for the needle. Then it was cut into strips the length of the needle, one end of which was hammered flat to form the head, and placed in the fire to soften. A well-tempered steel puncheon stamped out the eye. Then the corners of the flattened head were filed to the necessary roundness of contour and the other end filed to attenuation. Having been heated over a charcoal fire they were then submerged in cold water to harden. This was the crucial part of the process. If it was the least bit too hot or too cool, the needle was spoiled. A baking completed the operation of tempering. Then came the polishing in the emery dust and olive oil composition, the needles being placed in a piece of new buckram, which was done up in a roll tightly fastened at each end. The needlemaker then placed this roll under a stout plank, loaded with heavy stones, and for two days two men rolled this backward and forward, the friction of one needle against the other imparting a fine polish. Then came a washing in hot water and soap, and the drying of the needles in a box of bran.

The introduction of modern machinery has greatly facilitated needle making. Two years after the drill-eye machine was invented an effective burnishing machine came into use, but it was not until 1840 that the operation of hardening needles in water was abandoned. Owing to the action of the water many of the needles, though straight when immersed, came out crooked. The straightening of these needles employed an immense number of persons. In the year mentioned a needlemaker of Redditch, England, the principal seat of the industry, discovered the process of hardening in oil, which was so efficient that crooked needles were rare. The needle straighteners of Redditch, who formed a large part of the

population, and who were thus thrown out of employment, raised a terrific riot and ran the enterprising inventor out of town. The most important of the new machines for facilitating the industry is the pointing machine. Its introduction, as in that of the oil-hardening process, was attended with bitter opposition from the needlemakers whom it threw out of employment. The original machine was secured by the angry workmen and broken to pieces. The pointing machine feeds the needles from an incline plane to a grooved grindstone revolving at great speed. A rubber disk, moving with a lateral motion against the needles, causes them to turn while being ground. A machine which will take the steel bar and turn it out in cases of fine needles without the manipulation of the human fingers is attracting the attention of manufacturers, although as yet it has never been put to the crucial test. On the part of needle importers in this country, the report of such a machine is heard with skepticism. Its improbability seems apparent when one considers that even with the improved machinery now used, a needle must pass through seventy pairs of hands before reaching a marketable condition. They admit a machine may be possible for the manufacture of coarse needles, but they aver the making of fine needles to be an art, and in common with all true arts, secure from usurpation by the machine. But in the face of fully as great achievements in other industries, who shall deny the possibility of such a labor-saving mechanism in that of needlemaking?

The modern timepiece, with its delicate and exquisitely adjusted mechanism, is one of the marvels of the age. And yet watches are so cheap nowadays, and they have become such common luxuries—yes, even necessities—that people have almost forgotten the day of the old-fashioned, clumsy, hand-made affairs. The present perfection of

mechanism and cheapness of price of all kinds of timepieces are due solely to the invention of machinery for their manufacture. The principle on which the machine-made watch is built is that of the spiral spring motor and a train of wheels, of graduating circumferences. The spiral spring, or motor, is attached to the largest wheel by a little projection which is turned when the watch is wound. Turning this projection causes the spring to wind around it, where it is held in place by what is called a pawl. This tightly-wrapped spring naturally endeavors to unwind, and in so doing exerts a pressure of several ounces against the pawl, and the pawl being fastened to the body of the wheel, causes the wheel to turn around. In order that the spring will not unwind too rapidly there is a system of delaying mechanism. In the center of the second largest wheel is a small-toothed axle which is fastened to the large-toothed wheel, of which it forms the center. The teeth of the big wheel, inserting themselves in the teeth of the toothed axle or pinion, drive the smaller wheel as many times faster as the large wheel is greater in circumference than the pinion. The second wheel acts on the third, and the third on the fourth in just the same manner. The speed which has now been attained would be entirely too fast for use were it not regulated. This is done by what is called an escapement wheel, containing odd-shaped teeth, which can turn around only as the pendulum above it moves. It is impossible to use a pendulum, however, in a watch, so other means have to be used to oscillate the fork. This is done by what is called a balance wheel and a hairspring which counteract the velocity given the wheels by the mainspring in this way: The hairspring is curled up in the center of the balance wheel, and when the mainspring puts the train of wheels in motion and turns the escape wheel, the fork moves to one side, and in so mov-

ing winds up the hairspring. One tooth of the escape wheel slips by, and the released hairspring turns the balance wheel and moves the fork the other way, admitting one more tooth of the escape wheel, when the mainspring is again engaged. Thus the operation is repeated until the watch runs down. The compensation balance maintains the equilibrium of the machinery as regards expansion and contraction from heat and cold. This device consists of a series of small screws on the periphery of the balance wheel, and a proper adjustment of these screws has a tendency to make a watch run accurately at all common temperatures. Were it not for this delicate piece of mechanism an increase of twenty-five degrees in temperature would cause the watch to lose seven seconds an hour. On the fourth largest wheel of a watch is the second hand, while on the second wheel of the train, so-called because of its location, is the minute hand. When absolutely perfect adjustment of every part of the watch is secured, the center wheel will revolve once an hour, carrying the minute hand with it. The hour hand is carried by two additional wheels, so arranged that they revolve about the same center as the wheel carrying the minute hand, but without interference with each other's motion.

Of all the many improvements in the mechanism of the watch as we know it to-day, the stem-winding device is probably the most useful and important. Watches made on this system have also a setting mechanism, equally convenient and delicate. This consists of a small sliding lever which is pulled from the side of the case, or in many instances the stem itself connects with this setting apparatus, and is operated in connection with and similarly to the winding of the watch. In the better grade of watches friction of those parts sustaining the greatest amount of wear is obviated by minute jewels, usually rubies, which

serve as bearings. Without the jewel movement, a really excellent watch can be bought for a dollar, and it will keep good time for at least a year.

Machinery for the cheap and rapid production of buttons of all kinds is a notable acquisition to Nineteenth Century industry. Two hundred years ago there were not so many buttons in the whole world as one will find to-day in the smallest country "general" store, and each one of these buttons was made by hand. Less than fifty years ago there was not a single button factory in the United States and practically no machinery for its production in Europe. Buttons were strictly an imported luxury, and the common people had to put up with very common grades and not many of such kinds even, for buttons were an expensive convenience. Now they are so cheap as to justify the use of the phrase, "not worth a button." It is computed that the people of the United States alone unbutton one billion four hundred million buttons every night, when they get ready to go to bed. Samuel Williston, of Easthampton, Mass., started the button industry in the United States in 1848. Williston was a country storekeeper who failed in business, and whose wife covered buttons to eke out a miserable existence. Williston's attention being drawn to the subject, he soon invented a machine to do the work of covering the old-fashioned wooden button molds, which invention not only brought him a fortune, but excited the ambition of other inventors in the same direction. The machines used in making buttons are necessarily multitudinous, and although their product is simple the machines themselves are of the most clever mechanism.

It seems incredible, but is nevertheless true, that a greater quantity of steel is used annually in pen making than is consumed by all the gun, sword and needle manufactories

in the world. In one sense at least the pen can truthfully be said to be mightier than the sword. An yet the modern metallic pen of commerce is only about fifty years old. Like pins and nails, there is so much work about a pen that it is a marvel to the thoughtful how they can be sold as cheaply as they are. The only explanation is in the perfection of the machinery which manipulates them. In Birmingham, England, there are a number of pen factories, which turn out a total of 150,000,000 pens every week. To make a million pens a full ton of steel is required, of the finest crucible quality and rolled into sheets 7-1000 of an inch thick. Men perform this initial work on the pen—that is, they roll it to the required thickness. Then it is cut into strips as wide as two pens are long. When it leaves the cutting presses the steel is shaped like a pen, but is flat. The forms made by the presses are then put into a red hot furnace, and when thoroughly heated are taken out and permitted to cool slowly. Another set of presses hammers the points as well as stamps the name of the manufacturer. This done, the pens are reheated, and while still hot are cast into oil for the purpose of hardening. To clean and whiten them they are next boiled in water, to which soda has been added, from which they pass into a cylinder which revolves over gas jets. This process turns them blue, and they are then ready for marketing.

The history of American progress is contemporaneous with the growth of the paper trade, and that growth owes its evolution entirely to the labor-saving machinery which has been introduced into the industry. Chief among these mechanisms was the invention of Louis Robert, which revolutionized the paper business. This machine was perfected and patented early in the Century by Fourdrinier, and it remains to-day, with multitudinous improvements, the standard paper maker of the world.

In 1860 a German named Voelter perfected a system whereby wood fiber was substituted for rags, and the problem of still cheaper paper was solved. To such perfection has this process of Voelter's been carried that if the distance were destroyed the tall spruce tree of to-day might supply the fiber for to-morrow's newspaper. The material out of which wood fiber paper is made is usually spruce timber. The huge circular saws of this machine cut the logs into the proper length for the splitting machine; another machine removes the knots, after which it is but a short journey to the grinders, which reduce the wood into a pulp by huge revolving grindstones. From the moment the log leaves the hands of the grindstone feeder the work of man is finished. From that point until the huge white roll of paper is put into the packers' hands the machinery has done all the work. The pulp, in either its raw state as it leaves the pulp mill, or in the storage condition, is fed into the engine, which is a simple contrivance resembling the threshing machine in its construction. A cylinder covered with steel teeth revolves in a tub of pulp, which has been thinned with water. In opposition to this cylindrical motion is a bed of steel teeth, so arranged that those in the revolving cylinder will pass those in the bed. This process breaks the pulp into fiber of proper length and at the same time mixes the pulp with water. When the large vat of pulp has been reduced to the proper consistency the mash is transferred to a receptacle, where it awaits the call of the paper machine. The thoroughly mixed pulp is then fed on to an endless brass wire cloth, the meshes of which allow the water to escape as it moves. The wire cloth is kept in a vibrating motion, thus accelerating the flow of water and assisting in the knitting of the fiber. An endless web of felt takes the soft mass of refined pulp, and conducts it through several large,

cold rollers. This operation removes much of the latent moisture and presses the beds of fiber into closely knit strips, which are carried through a succession of hot rollers, whence the paper comes out dry and firm. The calender process completes the operation, and the paper is automatically wound into immense rolls measuring three feet in diameter. But the product turned out by the foregoing process is simply paper in its most primitive form, e. g., for wrapping or common printing uses. Inventors have not been contented to allow this commodity to remain in such a comparatively narrow field of utility. They have devised processes whereby we have paper car wheels, and to some extent, in Russia and Germany, railroad trains are run on paper rails. We have paper horseshoes, paper dress materials, trunks and dishes. In Japan paper houses are said to be common, and in this country paper boats are in daily use, as are also paper pipes for carrying water, steam and sewage.

The story of the hat is but an unceasing buzz of marvelous machinery from the moment the fur is deposited in the "devil," until it is ready for the wearer's head. The ordinary felt hat of the present day is made almost entirely of animal matter, the only vegetable material entering into its construction being the cotton back of the satin of which the linings are made. The fur which has been cut from the hide by a mechanical process is thoroughly sifted by the teeth of the "devil," a cone-shaped box through which a current of air passes. The fur is then ready for the blowing machine, the latest of which is an English invention. This machine consists of a box forty feet long and about four feet square. This process sorts the hair from the fur. The fur, being lighter than the hair, floats into one compartment, while the hair remains in another. Next is the forming machine, which consists of a wide oil cloth apron,

a pair of feed rolls, picker, a metallic drum, an open turn table and a powerful exhaust fan. The fan creates a current of air into which the fur is thrown from the drum to the cone. When the fur is all on the cone, just enough for one hat, it is wrapped in wet cloths and immersed in hot water, where it remains a moment before going to the hands of the hardener. Thence it goes to the "sizing" machine, the shaving machine and the "second sizing" machine, by which time it is ready for the stiffening process. Not until it has been blocked, however, does the cone of fur bear the least resemblance to a hat. The blocking, which is entirely mechanical, is done by immersing the bodies in hot water and shaping them, one at a time, over blocks suited to the hat's final style and shape. The dyeing process which follows that of blocking is also purely mechanical. Then follows the finishing. In this process the hat is taken to a steaming table where it is held in live steam until it becomes soft enough to pull over the block which gives the crown its final shape. After this follows the stiffening, curling and trimming operations, if it be a derby hat. Soft hats are treated essentially the same as stiff, except some details of the stiffening process. While there is still some hand work done in the later stages of the making of a felt hat in an American factory, such a thing is almost unknown in an English factory. During the last fifteen years there has been more machinery introduced into American hat factories than in any prior period. The honors for the invention of the improved machinery are about equally divided between England and America. While the English machines and systems have greatly improved the quality, the Yankee machines have made the present product possible, for without the forming machine, an American invention, the present output at present prices would be absolutely impossible.

A unique piece of automatic machinery invented for practical purposes is the slot machine. So numerous are they and so varied are the needs which they fill—and fill successfully—that they may justly be regarded as one of the great labor-saving devices of the age. The slot machine has ousted numberless human employes and filled their places with automata that do their work with superhuman precision and faithfulness. The chewing gum machine is a permanent institution. The chocolate machine, which only requires a cent to operate it, has to a large extent taken the place of the candy girl. Cologne, ice water and newspapers are dispensed also with a prompt hand by these mute servitors. There is also the machine that will ascertain your weight and print the amount thereof on a piece of paper. Another contrivance will test the strength of your grip, measure the expansive power of your lungs and tell you the extent of your stature in feet and inches, all for the sum of five cents, duly deposited in the slot. The plan of the slot machine is pretty much on the same principle whatever may be its particular mission. In the case of weighing machines, the mechanism is such that when the penny is dropped in the slot a coin of exactly the same weight and size as the penny falls into a little receptacle, and its weight turns what is technically known as a "dog." This "dog" releases the indicator, which flies around to the proper weight number on the dial, while the penny rolls through a metal cover into a canvas bag. The slot machine originated in 1887 in the form of what was known as the Grannis weighing machine. There seems to be no end of the possibilities of the slot machine, or the effects that can be brought about by the insertion of a coin and the corresponding turning of a "dog." One of the most marvelous of these machines is the automatic news dealer, which sells any size and weight of newspaper, from

the twenty-four page Sunday sheet to the smaller daily, and returns change when the price is under a nickel. It can also be set to make change for any coin and it cannot be cheated. It is the prediction of inventors that before many years have elapsed they will have perfected the slot machine so as to have it take the place of the bartender, the soda water clerk, and a host of other callings—all more or less indispensable to human welfare, pleasure or happiness.

Although restricted solely to the use of physicists, by far the most remarkable labor-saving mechanism in the world is the ruling machine in the physical laboratory of the Johns Hopkins University, at Baltimore. This marvelous machine, with its diamond point, rules 15,000, 40,000 or 125,000 lines to the square inch; which figures represent an amount of human labor not only infinite in duration, but absolutely impossible of attainment. This machine, designed by Prof. Henry A. Rowland, of the University, and constructed by Theodore Schneider, the machinist of the University, is for the purpose of ruling lines on polished pieces of metal so as to form what physicists call a "grating." All physicists and investigators of the sun's rays are dependent upon this little machine for their gratings, it being the only one in the world. The purpose of the grating is the dividing of a ray of sunlight into its component parts, the ordinary prism, which divides the ray into the seven primary colors being the simplest method. But the limit of research with the old-fashioned prism has long been passed, physicists being able to get further into the subject by means of the gratings, and the larger the number of gratings the better the ray is reflected. These lines are so close together that they cannot be seen with the naked eye, but under the microscope every line is perfectly distinct and absolutely accurate. Were there the slightest variation in the paral-

lelism the grating would be entirely useless for scientific purposes. It is claimed for Prof. Rowland's machine that if a diamond of sufficient strength could be secured a grating of a million lines to the inch could be procured. The machine sits on three legs and has a stout frame, the motive power being a little hydraulic engine. It is driven by a belt attached to a driving wheel of solid steel, a crank being turned at the same time on the other end of the shaft. This crank moves the carriage that pushes the diamond point back and forward over the surface of the grating. Every time the diamond makes a stroke the metal plate beneath moves an infinitesimal space. The carriage which carries the plate is moved by a steel screw. In order that this screw might be absolutely perfect it was ground under water kept at a certain temperature. If made in the air, or had the temperature of the water varied, the expansion would have caused the threads to vary slightly. This would have caused the carriage to vary, and as a consequence the spaces between the grooves would not be equal. Foreign universities have tried to make as good a machine, but without success. So the Rowland "gratings" supply the spectroscopes for all the universities of the world.

One of the most phenominal labor savers in the world is the giant crane used in lifting stone on the sea wall, constructed at Peterhead on the north coast of Scotland. It is capable of lifting one hundred tons, and can pick up a modern locomotive with as much ease as the same locomotive would draw a train of cars. It can lift the cubic contents of 100 car loads, and scatter the material over a wide section of the landscape. So long and powerful are its arms that it can set a sixty-ton block in the sea 100 feet deep and seventy-two feet from the outer edge of the masonry wall. The work of this machine alone displaced

two thousand men, who otherwise would have been daily employed on the building of the wall at Peterhead.

The perfection of mechanism obtained in very recent years has reduced the manufacture of sugar to a point where it becomes almost entirely automatic. The early part of the Century the life of the sugar-maker was synonomous with that of the traditional galley slave. Under a burning sky he cut the cane, stalk by stalk, with a common knife, a long and tedious task; then he piled it in tumbrels and carted it away to the "sugar house," where by a medieval process, and with much waste, it was converted into sugar and molasses. Now the cane is dumped on a cane-carrier, an endless traveling conveyor of wooden slats. This feeds the cane into the cutter, consisting of two large corrugated iron rolls, which crush and cut the cane into strips six inches long. This process extracts 60 per cent of the cane. The juice which has escaped into a tank below, is automatically pumped and strained into a higher tank, whence it flows into a large open caldron. Then the juice is boiled to evaporate the water. The vacuum-process pan, invented by Norbert Rillieux, of New Orleans, has completely superseded the old method of doing this, which method consisted of running the liquid through a series of open pans. The Rillieux vacuum pans are cylindrical tanks, with facilities for conveying the steam to the next pan. Inside each pan is a huge drum with copper tubes, through which the juice circulates. Exhaust steam of a temperature all the way from 190 to 208 degrees Fahr. is admitted into the drum and around the pipes. But the syrup does not boil, as a partial vacuum is maintained in that portion of the pan in which the juice circulates. The fluid is thus kept just below the boiling point sufficient to evaporate in the form of steam. The steam coming off the first vacuum pan boils the juice

brought in from the first pan, because a better vacuum is maintained in the second pan. From the second pan the exhaust steam passes on to the third pan in the same way, and if the process is of the "quadruple effect," it will in turn pass on to the fourth pan, each pan maintaining a better vacuum than the preceding. In the last pan the juice has attained the consistency of a thick syrup, when it passes into receptacles for cooling and crystallization. A machine which works with a centrifugal motion at the rate of about one thousand revolutions per minute stirs this mass. By centrifugal force the molasses is thrown out in three or four minutes. Centrifugal force entirely eliminates the molasses, while the grains of sugar have been retained in a rotating basket. The pulling of a lever puts this basket in motion, and it whirls about at a speed of one thousand revolutions per minute. The sugar when it comes out of this basket, after three of four minutes whirling, is white and ready for the refining process, in which there have also been many improvements and inventions. The sugar is first dissolved in hot water, and then pumped into tanks, whence it flows through a series of cylindrical filters. A vacuum pan operation, similar in principle to the first evaporation process, renders the composition absolutely dry. And after passing through another centrifugal machine it emerges as granulated white sugar. Machinery for the reduction of beet juice to sugar is on nearly the same principle as that used for the cane-sugar industry. The most popular of these machines is that which works on the diffusion process. By this method the beets are sliced and circulated in water until the saccharine matter is removed. The juice so obtained is then strained and put through a process of carbonic acid saturation, after which it is filtered and evaporated.

There is indeed scarcely any industry of any magnitude or importance whatever to which labor-saving machinery has not been applied. In the manufacture of brooms there have been such great improvements of methods in various departments that the number of broommakers of the United States has been reduced more than one-half although the product has more than doubled in quantity. In the manufacture of carpets recent processes have displaced twenty times the number of persons now necessary. By the old methods of spinning the carpet material it required seventy-five to a hundred times the number of operatives now employed to do the same amount of work. By the invention of the carpet-measuring machine, which measures and brushes the product simultaneously, one operator does the work formerly required of fifteen men. Carriages and wagons have also been affected by improved machinery. The one-time independent wagonmaker has suffered the same eclipse as has the shoemaker. In the instance of agricultural implements, labor-saving machinery has displaced fully 50 per cent of the muscular effort formerly employed. Improved methods of brick-making have displaced 10 per cent of labor. In the making of fire-brick 40 per cent of the labor employed is now unnecessary. In the cutlery industry the machine has usurped an incredible amount of labor as it has also done in the manufacture of small arms. Where it formerly required the continuous work of one man for ten hours to fit one stock for a musket, by use of powerful machinery three men can turn out and fit 150 stocks in the same length of time. The scrubbing machine, designed chiefly for the cleaning of colossal office buildings, is already displacing scores of women scrubbers in every large building in which it is placed. A bread kneading machine recently put into operation in San Francisco is

doing the work formerly done by a hundred men. The painting machine used to whitewash the buildings at the World's Fair was operated by two men, who by its aid, did as much work as 200 men working by hand. The mimeograph, the patent letter-press, and a host of other office conveniences have dispensed with an immense amount of clerical help in the business world.

The remarkable machinery that has been invented for all manner of work is not more wonderful than the machinery, or machine tools which make the building of such mechanisms possible. The forming of a hole for a screw, a bolt or a rivet is apparently a very simple operation, but to do this work accurately and rapidly has engaged the attention of the most ingenious minds of the day, and as a result there are drilling machines, boring machines, punching machines and riveting machines innumerable. As a labor-saving mechanism nothing can be more efficient than the multiple drills that have made their appearance only in recent years. Among these are the two- and three-spindle drills which make the holes by which railroad ties are connected. There are the four-, six-, and eight-spindle drilling machines for boring holes in rows at spaced distances. A universal drilling machine, built by William Sellers & Company, drills a hole in any direction. A radial drilling machine, built by the same firm, will make a hole anywhere in any direction within a radius of eighty-three inches. Boring machines, of both horizontal and vertical form, have done much towards the production of cheap machinery. Punching machines, capable of exerting a punching force of half a million pounds, multiple punching machines, capable of making six holes at once, and punching machines combined with machinery for shearing, are some of the colossal examples of recently invented machinery. Shearing machines designed for trimming the edges

of iron plates can cut off an edge sixty inches long and an inch thick. Riveting machines, of a strength and capacity sufficient to fasten a rivet in the center of a plate thirty-two feet square, are a leading factor in the making of boilers. There is also the wheel-press, which exerts a pressure of thirty tons when employed to put a car wheel on its axle. There are planing machines to reduce a level surface by shaving in parallel lines. Rotary planers, having all the way from twenty-five to seventy-five tools affixed on a wheel, are much used in bridge-building. The mortising of door frames is done by means of the slotting machine, which is invaluable as a labor saver. For finishing and shaping the parts of machinery there is employed what is called a milling machine, which operates by means of rotating cutters. Stamping presses, used to shape parts of metal, are almost indispensable in all branches of machinery making; a special machine of this kind is that used in the Philadelphia mint. This exerts a pressure of two million pounds. Machines for the bending and straightening of plates, for forging, and for grinding drills are other mechanical triumphs in this category.

There are few branches of mechanical construction which do not employ their own peculiar lathe, but they are all constructed on the same principle—that of a frame having a pointed center at each end. One of these is called the live center, because it has a rotary motion, the other is the dead center, it having no motion. The work to be turned is hung between these centers. The mandrel of the live center is propelled by pulleys, and the cutting tool is mounted on a carriage in such manner that the operator can guide it back and forth over the surface of the material, cutting it in almost any circular or conic form. The greatest achievement in the way of such a tool is the Blanchard lathe, so-called from its inventor, and which is so perfect

in its mechanism as to be able to cut material into almost any desired shape. Strange as it may seem, by its use articles in shape so unlike in geometrical forms, as gun-barrels, shoemakers' lasts, etc., can be turned on a lathe. It is as simple a contrivance as it is wonderful. In an ordinary lathe the work revolves rapidly and the cutting tool is stationary or only shifts its position slowly to accommodate fresh portions of the work, while in the Blanchard lathe the work is made slowly to rotate and the cutting tools revolve with great rapidity. The pattern and work being fixed in similar and parallel positions they always continue so at every revolution. The whole arrangement is self-acting so that when once the pattern and the rough block of wood are placed in position the machine completes the work and reproduces an exact duplicate of the shape of the pattern.

LIGHT AND HEAT—INCLUDING PHOTOGRAPHY

The Nineteenth Century has witnessed a marvelous revolution in methods of producing and utilizing light and heat. The rude processes in vogue at the end of the last Century were almost exactly the same as had been in use for the preceding two or three thousand years, and they were at that but slight improvement on the customs of savage and barbarous nations.

The history of fire as a light giver is both picturesque and interesting. It is thought to have been first utilized in volcanic districts, where sticks of wood can sometimes be ignited by thrusting them into subterranean cavities. The theory has also been advanced that primitive man came into its possession through the agency of the electric storm, when trees might have been set on fire by lightning strokes. Or, as it is known that trees are sometimes fired by friction of dry branches, it is not impossible that prehistoric man became acquainted with the fierce element in that way. But by whatever means he did become familiar with fire—and it may have been any or all of these phenomena—the astute savage recognized its usefulness and the necessity for its preservation, and, at a presumably later age, discovered that he could produce it himself by friction.

This primitive custom, descending to civilized peoples, in time evolved into the more convenient flint and steel process, which probably did not originate until after iron was made. Thus the method of fire-getting by the rubbing of one substance on another continued in use

from the days of prehistoric man, through all the ages of barbarism and civilization until early in the present Century, with practically no improvement in all that period.

And then a great discovery was made. In April, 1827, John Walker, a chemist and druggist of Stockton-on-Tees, invented a fire-getting implement which consisted of a splint of wood tipped with a solution of chlorate of potash, sulphur, starch and gum, which ignited by friction on sandpaper or glass, and to which he gave the name of congreve, in honor of Sir William Congreve, inventor of the rocket. Thus the English druggist solved the problem that had baffled the ingenuity of science for more than one hundred and fifty years. The alchemists of the Seventeenth Century had not been unacquainted with the properties of phosphorus, which was discovered by Brand in 1673. He and his contemporaries experimented with the new fire-producing chemical in the hope of substituting it for the old flint and steel sorcery, one of their processes being to rub a bit of it between two sections of coarse paper and allowing the spark of fire to fall upon a "spunk." But the method was inconvenient and impracticable, and, as the use of phosphorus entailed considerable danger, it soon fell into disuse, and the old-fashioned flint and steel process was resumed. Another chemical discovery at the beginning of the present Century gave further impetus to such an invention and ultimately led to the match as we know it to-day. The chemist Berthollet accidently discovered what he termed the "principle of the oxidation of combustible bodies by chlorates in the presence of strong acids." Chancel, in 1805, made practical application of Berthollet's discovery and produced his so-called "oxymariate" matches. These consisted of strips of wood dipped in

a mixture of chlorate of potash, sugar and gum, and were ignited by contact with sulphuric acid. As early as 1780 there had been in use an "electro-pneumatic fire producer," in which a jet of hydrogen was lighted by an electric spark. The Dobereiner "platinum lamp" came into existence in 1823. In this hydrogen gas was ignited by contact with spongy platinum. During the use of the platinum lamp there had also appeared in parts of Prussia a device consisting of a small glass tube, containing equal parts of phosphorus and sulphur carefully mixed together. Splints of wood were thrust into this, and the friction caused ignition.

John Walker's invention, modeled after the idea advanced by Berthollet, was, however, the real precursor of our present day match, and even that had to be greatly improved upon before it was rendered practical or satisfactory. The Walker match contained no phosphorus, the absence of which was responsible for its not being a success commercially. In 1833 wooden friction matches containing phosphorus were manufactured in Vienna, Darmstadt and other European cities, and the use of the new implement spread rapidly. On October 24, 1836, A. D. Phillips, of Springfield, Mass., took out the first patent in the United States for a phosphorus match, the igniting composition being a mixture of sulphur. By this time the people commenced to gain sufficient confidence in the innovation to throw away their ill-smelling and clumsy old tinder boxes, and matches came into use all over the civilized world. A warm discussion on the dangers attendant on the use of phosphorus in match making took place between the years 1840 and 1865. It was claimed that the matches in use were not only dangerous by reason of their being rankly poisonous and highly inflammable, but the workmen employed in their manu-

facture were subject to a peculiar disease of the jawbone, which was loathsome and eventually fatal. This outcry, which was raised all over Europe and America, gave inventors an incentive to discover processes and compositions that would reduce this danger to a minimum, if not wholly remove it. Lundstrom, of Jonkoping, Sweden, invented the first safety match in 1855. His process consisted in putting the oxiding mixture on the splint and what is known as red phosphorus (a safe form of that chemical) on the box. The new match was a great improvement on the original, and led to the discovery of other non-dangerous igniting mixtures. The use of the safety match was enforced by law in various countries of Europe, and to this day the use of Swedish safety matches only is allowed in Denmark and Switzerland. In late years, however, by the enforcement of regulations regarding ventilation, cleanliness, and the impregnation of the air of the factory with turpentine fumes, matchmaking has been relieved of almost every element of danger to its workers, and the match itself is quite as harmless as its cumbrous predecessor.

Rivaling in importance the improvement in the process of fire-producing, are the advances that have been made in the methods for its utilization for illuminating purposes. From a tallow candle to an arc light is a far cry, and yet less than a Century ago even the common oil lamp as we know it to-day was unheard of. The nearest approach to the modern kerosene lamp was a rudely constructed vessel filled with melted animal oil and enclosed in a glass case, and which was really the original prototype of our modern lantern. What was called a lamp consisted of a small earthenware cup and contained melted animal fat or vegetable oil into which a wick was introduced. The wealth and nobility of the

world had no better means of illumination than had the simplest laborer. The gold and silver vessels in the palace were the exact counterparts of the crude clay lamps in the peasant's cottage. For out-of-door lights torches were used almost exclusively in the cities, and their mode of preparation differed very little from that employed in the middle ages. They were made of the twigs of resinous woods tied together in a bundle and mounted on a tall sapling or post. For all practical purposes the tallow candle and the more elegant wax taper stood paramount at the beginning of the present Century. It is almost impossible to realize that we have been using lamp chimneys not quite one hundred years, and that the Argand burner, although invented late in the last Century, was not sufficiently improved and cheapened to come into general use until 1830. While not so glorious as the discovery of electric light and of coal gas, the invention of the Argand burner and the subsequent application of the glass chimney as a means of supplying a regular current of air to the flame, marked a distinct epoch in civilization.

So perfect has the common oil lamp now become that with the use of the cheap mineral oils, its light in many instances rivals that of the gas jet or the incandescent lamp. And yet these very mineral oils, almost as plentiful as water to the present generation, were practically unknown to the people of the last Century.

Next in importance to the improvement of the oil lamp as a means of illumination was the discovery and introduction of coal-gas, which belongs almost exclusively to the category of Nineteenth Century achievements. Although his first experiment took place in 1792, it was not until 1802, on the occasion of the celebration of the Peace of Amiens, that Murdock, a Redmuth engineer,

made a public display of his process of utilizing the gaseous products of coal for illumination. Though Murdock was the first to put gas to a practical use, he was not its original discoverer. So far as can be learned, that distinction belongs to a Dr. Clayton, who, about a hundred years before, had conceived the idea of heating coal in such a manner as to force out and retain its gaseous constituents. He left an interesting description of his experiment, which he evidently considered more in the nature of a huge joke than anything else. He tells us how he first obtained steam, then black oil, and at last a "spirit"—spirit being the name used by our forefathers in the discription of any gaseous substance. Dr. Clayton, according to his chroniclers, utilized his discovery as a means of entertainment for a select coterie of friends, to whom the sudden ignition of the "spirit" when touched with light, caused immense amusement.

And so it remained until Murdock's time—a chemical wonder—a mysterious and evil-smelling "spirit." In 1807 a few gas lamps were placed in the streets of London, but not until 1813 did its use become at all general. In that year Westminster Bridge was illuminated with it, and then it came rapidly into use, not only for lighting private houses but for dwellings and public buildings. Like all innovations, it met with fierce opposition in every direction. Even so great and good a philosopher as Sir Humphrey Davy was exceedingly derisive in his expression of opinion regarding the new illuminant. At first he went to the length of declaring that it was absolutely impossible to light London with gas—little dreaming that he was at that very time perfecting a system of lighting infinitely more dangerous to time-honored fallacies than was the objectionable and new-fangled gas. America welcomed the innovation in much the same spirit

as did Humphrey Davy. Philadelphia fought for more than twenty years against its introduction as a means for lighting the city. Peale, in his museum in the State House, had as early as 1816 or 1817 produced a fine illumination through the use of gas obtained from a private plant belonging to a man on Lombard Street, whose dwelling was probably the first in America to be lighted with gas. Peale was immediately enjoined from continuing his luminous exhibition, as it was declared to be a menace not only to the historic old State House, but to the entire city as well. It seemed almost impossible to overcome the general prejudice which resisted every attempt to establish a first-class plant in Philadelphia; this was also true of cities all over the country.

The United States Gazette declared it a folly and a nuisance, and insisted that common lamps would "take the shine off all the gas lights that ever exhaled their intolerable stench." All manner of objections were brought against the obnoxious fluid. The newspapers dwelt emphatically on the dire warning that the introduction of gas would result in terrific carnage and destruction, and that the refuse of the works would kill the fish in adjacent streams. Even from the University of Pennslyvania came the voice of Professor Hare, protesting that even if gas were the good thing which its supporters declared it to be, tallow candles and common oil lamps were good enough for him. On March 23, 1833, a formal petition of remonstrance, signed by twelve hundred of the wealthiest citizens of Philadelphia, was carried to the State House. The contention waxed so hot that a special commissioner in the person of Samuel V. Merrick was sent by the council to London and Paris for the purpose of investigating the lighting facilities of those cities. Upon favorable reports from the commis-

sioner, the Council, with much misgiving, reluctantly granted the long-fought-for ordinance. After the victory in Philadelphia, the use of gas spread rapidly all over the country, with the result that now every great coal region has its corresponding area of coke ovens, or gas retorts. These retorts are huge cast-iron vessels, covered with brick masonry, beneath which a large furnace burns continuously. The various volatile constituents of the coal are distilled in such manner as to allow the gas to escape into a reservoir, where it is purified and made fit for use.

The discovery of oil pools of fabulous contents in America not only had a great influence in bringing about better illumination for the great middle class, but it introduced a new kind of fuel, which, for a time, appeared to be inexhaustible. The same territory which produces pretroleum also abounds in greater or less deposits of natural gas, which for a number of years now has served the purpose of fuel to a large part of the population of the United States.

But the use of gas for heating purposes is not restricted to the radius of territory fortunate enough to produce the natural element. The manufactured product is fast taking the place of coal all over the country, for cooking purposes at least. It has been proved to be the best and often the most economical cooking power in existence, as there is no waste to it as with coal. With the development of improved and inexpensive processes for the manufacture of gas, who shall say that the day may not come when the coal fire will have entirely disappeared? Who knows but that a few generations hence the use of the begriming mineral as a fuel in its natural state will be as archaic as would be to us the use of the flint and steel?

The story of the discovery of acetylene gas might be called one of the romances of science. The new illuminant had been known to chemists for years, but the difficulty of its manufacture prevented them from using it. In 1895 T. L. Wilson, of North Carolina, while superintending the production of aluminum by the electric smelting process, noticed a by-product of the operation, the nature and character of which was unknown to him. Upon throwing the substance into a bucket of water a gas was given off, whose chief characteristic seemed to be its penetrating and disagreeable odor. On applying a light Mr. Wilson discovered that the gas burned freely with a luminous flame. A repetition of the experiment proved the unknown substance to be calcic carbide. It was found that a pound of this calcic carbide would yield 5.3 cubic feet of acetylene gas, and a company was formed to manufacture the gas on a large scale. From an economic point of view this gas is of great value, for it can be generated in a house as needed, by a very simple apparatus. Perhaps the most remarkable quality of the gas is the fact that it can be liquified by pressure and put in cans that can be tapped when the gas is needed. A very simple device has been arranged by which the pressure of the gas can be regulated while changing from its liquified condition, and then pass into the various pipes. Acetylene is a most powerful illuminant. It is dazzling in the brightness and steadfastness of its flame, and for this reason is much used in the illumination of bicycles and carriages. It has been conjectured that it may in time supplant coal gas in the illumination of streets, thereby doing away with gas piping, for it is said that lamps can be made in such manner as to generate the gas on the spot. It has been proved that the acetylene can be manufactured at one-third the present cost of coal

gas, and in view of this fact it is entirely possible that if the discovery proves as practical as claimed, it will revolutionize the manufacture of gas.

We have already observed Sir Humphrey Davy's attitude in regard to the projected illumination of London by gas-light, and in consideration of the discouragement which he lent that scheme there is a prophetic significance in the fact that in the very first year of the Century he should himself have made an experiment that resulted in the discovery of the electric light as we know it to-day. The electric spark had been familiar to the earlier experimenters with electricity, but not much more familiar than it had been to the ancient philosophers. But it remained for the magic of the Cornish philosopher to seize the evanescent spark and make it burn into a brilliant glow by passing it between two points of carbon. The instrument used by Davy in this memorable experiment was a voltaic battery of 2,000 elements. On separating the two carbon points a very small distance, he saw that the gap was bridged by a slightly convex flame which remained until the distance reached a certain limit, at which limit the arc disappeared and the points quickly became cold. The carbons when slowly brought toward one another did not display any activity or calorific phenomenon, but as soon as they were brought in contact the points became hot, and as soon as separated the arched flame burst forth again. Davy gave this convex flame the name of voltaic arc, and it has been so known ever since. The voltaic arc, however, is not a true flame, there being little combustion; it is rather a nebulous blaze resultant from the incandescence of a jet of particles detached from the electrodes and projected in all directions. The positive carbon has a much higher temperature than the negative, which is scarcely a dark red

when the positive carbon at the same distance from the arc is a reddish white over a considerable length. The consumption of the positive electrode for a given time is twice that of the negative. The action of the arc upon the electrodes may be described as that of a trembling blue flame of ovoidal form, into which brilliant particles leap from one carbon to the other, producing a luminous red flame. When the voltaic arc is produced in the air the electrodes diminish rapidly, as both of them burn, but in a vacuum this combustion does not take place. The positive carbon becomes hollow and diminishes in weight and the negative elongates and increases in volume. When the wasting of the carbons widens the arc too much, the current is broken and the light disappears, and to obviate this the modern arc-lamp has an automatic mechanism, the function of which is to feed the carbons forward to the arc as they are gradually consumed and thus maintain the splendor of the illumination.

Arc-lamps constructed on the principle discovered by Davy constitute the most luminous artificial light of the present time. Many ingenious lamps have been invented, all embodying the one original idea. Those devised by Serrin, Siemens, Brockie and Duboscq are probably the best known. Some of them regulate the arc by clockwork and electro-magnetism, and others by thermal effects of the electric current. They are used principally for out-of-door illumination, for large areas, streets, railway stations and lighthouses. In the latter instance the arc is placed exactly in the focus of the condensing lenses of a parabolic mirror, which projects the rays all in any one direction, the beam being visible for thirty miles on clear nights. Specially constructed arc-lights, equivalent to hundreds of thousands of candles, can cast a beam of light a distance of one hundred and fifty miles.

Davy's discovery that a continuous wire or stock of carbon would become white-hot by subjecting it to a current of sufficient strength forms the basis of the modern incandescent electric light. Vacuum incandescent lamps are the only ones which have come into general use. Systems based on the incandescence of carbon or platinum in the open air have been tested, but as yet have not come into practical use. In 1841 De Moleyns patented in England an apparatus for the production of light by the incandescence of platinum wire in a closed glass globe, but the scheme was a failure. In 1845 Starr of Cincinnati invented an incandescent carbon lamp on the same principle, and with the same result. Experiments were also made by De Changy, Lodyguine, Kohn and Swan, with little more success. In 1880 Edison constructed an incandescent lamp that was really satisfactory and of commercial value, and although twenty years have not elapsed since its invention it has reached a state of apparent perfection. The Edison lamp consists of a carbon filament fixed to two platinum wires, a glass bulb in which a vacuum has been formed, and a threaded base inserted in the neck of the bulb and intended to hold the lamp in its socket.

The filament used is a vegetable fiber, to which definite form is given according to its nature, either by means of a die or between cylinders, or by cutting it out while in a plastic mass. The fiber thus obtained is subjected to heating by incandescence until it becomes a dense and resilient carbon. Platinum is used because its properties of expansion and contraction are about the same as those of the glass bulb. The vacuum in the bulb is induced by a mercurial air pump. One end of the filament being inserted in the bulb, the other is connected with the metal screw ferrule at the base of the socket, and when screwed

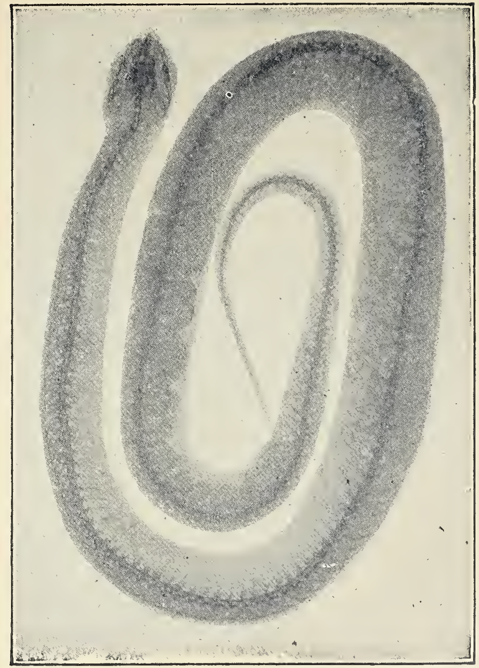
into the socket there is an automatic connection between the sensitive filament on one end of the screw and the insulated plate at the bottom of the socket. Such is the principle upon which all incandescent lamps are constructed, the only variations being in methods of preparing the filament and of clamping the wires.

From a sanitary and æsthetic standpoint the electric lamp is perfect. Properly shaded it will shed a light that equals the moon-beam for softness; or it can be made to rival the sun in brilliancy. It is pure and healthful, as there is no pollution of the air from combustion. It is not inflammable, and for this reason there is absolute safety from conflagration. It illuminates the street, the home, the office and workshop. It lights our railroad trains, steamships, street cars, carriages and even bicycles. It lights the miner at his toil far down in the bowels of the earth, and it accompanies the diver to the bottom of the ocean. It penetrates the darkness of the seas, throwing a shaft of light many miles in advance, and in war time it turns a powerful searchlight on the operations of the enemy. In the large cities of the country night may be turned into day for all practical purposes. Electric lights are hung high in the air on towers placed at convenient intervals, illuminating immense areas and leaving comparatively few dark spots within the limits of a great city. Indeed the magic of Aladdin's fabled lamp was not more potent that has been the sorcery wrought by the Nineteenth Century wizards when they gave the electric light as a perpetual legacy to an incredulous and marveling world.

But illumination is not the only function of electricity. When the voltaic arc was first discovered, one of its most marked peculiarities was the intense heat which it emitted to the electrodes in action. The chem-

ists, in testing this heat, found that it would melt not only all the metals, but quartz, ruby and even diamond, the hardest substance known. They discovered that the temperature of the opposing carbons was comparable only with the sun, and that they registered 5,000 to 10,000 degrees Fahrenheit, the highest artificial heat known. Sir William Siemens, about the same time that he was constructing his arc-lamp, also invented an electric furnace heated by the voltaic arc. In this furnace Siemens was able to vaporize metallic ores of all kinds. The application of electricity for heating purposes was until recent years confined only to the chemical laboratory, but since electric light has proved to be so great a success, electric heating for all purposes bids fair to soon become fully as important as electric illumination. The electric arc is now applied freely in the iron and steel industries for the welding of boiler plates, wires, rails and indeed all kinds of metal work. It is also used with great success in the heating of railroad trains, carriages and dwelling houses. Cooking by electricity is coming more and more into favor. Kitchen ranges, entirely heated by the electric current, are used in many of the best hotels and fine dwellings of the country. There have also been invented a number of cooking utensils equipped individually with batteries for the generation of the electric current. The principle on which all such articles are based is that of incandescence, the current flowing through a network of fine wires of platinum covered with fire-proof insulating cement in its bottom. The electric radiator is constructed pretty much after the fashion of the steam radiator, which it resembles in appearance, the heat from a strong current being diffused over an area of highly resisting metal. The devices for the utilization of electric heat that have been patented in

Man's Elbow, showing wounds caused by three pieces of shot



Coluber Natrix
Length, 94 cm.

ROENTGEN RAYS RADIOGRAPHS

the past few years are unique and numerous. It is now possible to have bed clothing heated to any degree and a constant temperature maintained, by means of a fine wire network enclosed between the quilts and connecting with an electric current.

The stoves in use at the opening of the Century would be unrecognizable as such at the present day, and as for kitchen ranges, they were unknown and unheard of. The common method of heating an apartment was by the use of the open fireplace, which also served for cooking purposes, except in rare cases. The Franklin stove, invented in 1745, was a great advance over the older forms, but it did not come into general use until the beginning of the Nineteenth Century. It has been described as a rectangular box of cast iron plates, open in front with a sliding shutter, by which the whole might be closed either entirely or partly, for safety or for increasing the draught. The hearth projected in front, and was cast with double ledges to receive the edges of the upright plates, and also with a number of holes, one in the front part for admitting air to the fire from an air flue beneath when the shutter was down; one behind the first upright plate in the back for discharging the air; and three holes near the extreme back edge for discharging the smoke into the flue leading to the chimney. This unsightly monstrosity embodied the principles of the modern air-tight stove, which art and an understanding of hygiene have since combined to make a healthful heating apparatus.

One of the most curious properties of light is its ability to trace images under certain conditions. Like electricity and gas, photography owes its real discovery and virtual development to Nineteenth Century wisdom. The story of photography virtually dates back to the year

1556, when the alchemist Fabricius observed the effect of light upon luna cornea, or horn silver; or chloride of silver as we know it to-day. In its native state horn silver is completely colorless, but so soon as exposed to the light of day it assumes a violet tint. It was not until 1727, however, when a German physician, Johan Heinrich Schultze, of Halle, attempted the taking of copies of some written characters on translucent paper, with very little success. In 1777 Charles William Scheele, a Swede, experimented with the discovery of Fabricius. He discovered that the rays of light are of varied chemical activity. A few years later Senebier made the very important discovery that violet rays of the spectrum analysis blackened chloride of silver as much in fifteen seconds as red rays did in twenty minutes. In 1801 Ritter of Jena added still further results to these discoveries. Wollaston, the celebrated English chemist, discovered that gum guaiacum, when exposed to blue rays, changed in color, and that those altered portions regained their original tint when exposed to red rays. The French claim that the first photograph was taken by Professor Charles during the course of a lecture delivered by him at the Louvre in 1780, the so-called photograph being a silhouette of one of his pupils. There is, however, no authentic report of the Charles experiment.

From the early history of photography it would appear that it was the amusement of all the great philosophers. We find Sir Humphrey Davy dabbling with the science such time as he was not employed in the development of his voltaic arc. In company with Thomas Wedgewood, son of the famous potter, Davy made a number of experiments, the results of which were set forth by him in the Journal of the Royal Institute in 1802. One of the most important of the experiments

made by them was what they called sun-drawing, which consisted in placing a solar microscope in the aperture of a camera obscura for the purpose of imprinting on sensitized paper the image produced on the screen. Wedgewood and Davy met with no success in any of these sun-drawing experiments, and it remained for M. Niepce, a French scientist, to continue them with so much success that he is justly entitled to the honor of making the most suggestive developments in connection with the discovery of photography. From 1801 until the end of his life, Niepce devoted himself to his idea of heliography (from helios, the sun). The difficulty encountered by Wedgewood and Davy was obviated by Niepce's discovery that asphalt will become soluble in certain oils. Mixing the asphalt with oil of lavender, he poured the solution over a metal plate, allowing it to dry and form a film. When placed where the image of the camera obscura fell upon it, the result was that the asphalt remained soluble where the shadows had fallen, but became insoluble where the light had struck the film. By several hours exposure in the camera, and a subsequent application of essential oils, Niepce secured a heliograph traced upon the metal plate in lines of asphalt.

The name that is most familiar, however, in the history of early photography is that of Louis Jacques Daguerre, to whom for many years was accorded the chief honor of the invention of photography. Daguerre was a painter of opera scenes and the producer of panoramic views, the pictorial effects of which he heightened by an ingenious use of reflected and transmitted light. He became acquainted with the camera obscura in his endeavors to obtain his first sketches from nature. In 1839 his famous spectacular exhibition, Diorama, which was the wonder of Paris, was destroyed by fire, and then

the artist devoted himself to the process of photography, which afterwards made him famous. Some years before this accident Daguerre had become a collaborator with Niepce, and until the latter's death, in 1833, they worked together on the heliograph process. The discovery of the daguerreotype was purely accidental. Several plates that had been under-exposed were placed in a dark room in which were various chemicals. The plates were thought to be useless, as no images had appeared. Some time afterwards, in searching for something else, Daguerre discovered the discarded plates, and, to his amazement, there was a picture on each one of them. He accounted for the phenomenon only by the fact that the plates must have been exposed to the action of some chemical lying in proximity to the plates. Removing the chemicals one by one, he discovered that the secret of the art was concealed in a vessel of mercury, which evaporates at an ordinary temperature. This incident occurred some years subsequent to Niepce's death, and according to the terms of the agreement he made with Daguerre, his name would also have been attached to the discovery, had it not been that after Niepce's death his son relinquished this right for material considerations.

Thus far photography had only been employed upon metal. Henry Fox-Talbot, after years of faithful experiment, solved the problem of "fixing" a photograph on sensitized paper. In the year 1850, the collodion-film on glass was perfected and came into use as a sensitizing material. This method produced as beautiful a likeness as the daguerreotype itself and at much less cost. Shortly afterward positives were printed from the transparent negatives on properly prepared paper, and thus the process now in use was initiated. There have been endless modifications and improvements upon the original

method, mainly to the end of increasing the sensitiveness of the plates so that quickly moving objects could be photographed with lifelike accuracy.

It has long been the dream of photographers to discover some method by which they could produce photographs in all the colors of nature. Thus far the process has not been perfected, but the developments of the past few years are extremely encouraging. Soon after he had heard of photography, in 1837, Sir John Herschel was led to experiment with the spectrum in the hope of fixing the natural colors of the image. Herschel succeeded only partially, but it was enough to incite the ambition of every photographer and scientist from that time down to the present. Edmund Becquerel, Niepce de St. Victor, Poitevin, St. Florent and Captain Abney ably followed up the research started by Herschel. The method adopted by these early investigators consisted in exposing the properly prepared plate to the light of the spectrum until the different colors were impressed on the negative. But the trouble was that as soon as exposed to the light the colors faded, there being no chemical to fix them permanently. In 1891 Professor Gabriel Lippmann, of Paris, introduced a new process, which was a distinct advance toward the solution of the problem of color photography. The method employed by him is on the principle of "interference" instead of chemical action, and is exemplified in the colors of soap bubbles, mother-of-pearl and other iridescent objects. Professor Lippmann explains it as follows: "The film in which the photograph is taken may be made of any substance, provided it is transparent and grainless. Exposure takes place in contact with a metallic mirror. The effect of the latter, which is formed by running a layer of mercury in behind the film, is to reflect back the incident colored rays, and thus make the

incident waves stationary. The stationary vibrations, falling in the interior of the sensitive film, impress their own structure upon it, and by virtue of the structure thus imparted, the brown deposit of silver, when viewed by reflected white light, appears imbued with the same colors as are possessed in the image in the camera."

Professor Lippmann declares that the colors produced in this way will be perfectly true if exposure and development are right. Development and fixing are effected in the ordinary manner, and the only drawback to the practicability of the process is that it has thus far resisted all attempts to reproduce prints from the negative.

It would be difficult to name a branch of industry or science which has not been benefited by photography. The applications to which it has been put are quite as marvelous as the art itself. Late in the year 1895 a great sensation was caused throughout the civilized world by the announcement that a German scientist, Professor Röentgen, of Würzburg, had succeeded in photographing the bones of the hand through its covering of flesh by the agency of rays proceeding from a spherical glass tube. The instrument by which the New Photography was first observed is known to scientists as the Crookes' tube, so called from the fact of its first experiment in England being made by Professor Crookes. Some twenty years before Röentgen made his discovery, two German physicians, Hittorf and Goldstein, made some interesting experiments with these tubes, which may be described as glass cylinders from which the air has been exhausted. In each end of the tube is placed a disk, one of which conveys an electric current to the interior of the tube, and the other carries it away, making the return wire to a battery. The generation of light takes place when the

proper fluorescence is obtained within the tube, and it is caused by the action of the electric fluid in disturbing the molecules of rarified air. In the experiments made by Hittorf and Goldstein it was observed that the light visible to the eye, passing from one electrode to the other, was due to the imperfection of the vacuum, and that the greater the vacuum became the weaker the light was until it disappeared entirely when a perfect vacuum was rendered. It was further noticed that with the disappearance of the light the tube became fluorescent, which indicated that the fluorescence was caused by the oscillating discharges of invisible rays, and that the cathode was the point of origin.

About a year prior to the Röentgen discovery Lenard, of Bonn, published a report of certain discoveries he had made in "shadowgraphs," as he called them. He proved that it was possible to obtain shadows of objects through practically opaque substances, and to make impressions of these shadows on photographic plates. For some unexplainable reason, however, Lenard's paper attracted very little attention, and was almost forgotten when Röentgen's discovery was announced.

The light generated within the tube is intensely luminous, but it is luminous in an entirely different way from ordinary light. It has the peculiar properties of rendering translucent objects which to us are opaque, and vice versa. Slate, wood, leather and carbon are much more transparent to the X-rays than glass, some varieties of which are entirely opaque to their light. Paper absolutely opaque to the fiercest ordinary light, is so transparent when subjected to X-rays that the light will pass through a book of a thousand pages. Flesh and skin are transparent, while bone is opaque; hence the value of the discovery in surgery.

Numerous theories and suppositions have been extended regarding what the X-rays may in reality be, and to account for their phenomena. Some scientists hold that they are ultra-violet rays of light with vibrations a million times greater than ordinary light; another is that they may be the missing longitudinal waves in the ether. If the latter supposition ever leads to anything tangible it will open up an entirely new department of physics, and may lead to discoveries of which we do not now dare dream.

Scarcely less of a surprise than the X-rays to the world was the development of photography in the form of the Cinematograph, the Kinetoscope, the Theatrograph, etc., etc., all of which might be properly termed "animated photography." The first patentee of this interesting application of the photographers' art was W. Friese-Greene, who invented a camera in 1889 for the rapid taking of consecutive photographic views; combined with the camera was an optical lantern which threw the images of the camera upon a screen, and by means of a handle the successive pictures were moved so rapidly as to give the appearance of life. The idea was not exactly new. It had been experimented with before by both Marey and Muybridge, and was known as the zootrope or the wheel-of-life. But Friese-Greene was the first to construct a machine for popular purposes. About the same time that Friese-Greene was taking out his patent Edison came forth with his Kinetoscope, constructed on the same principle. The Kinetoscope was soon followed by the Cinematograph and various other inventions, all embodying the same idea, and designed for the same purpose—that of amusement. These apparati have since become so perfected that they can present a moving scene with almost lifelike fidelity.

The application of photography to the printing industry has been of incalculable value to civilization, in that it has had a tendency to materially decrease the price of books and engravings. These applications have been many, but the chief one is the process of photo-block printing, invented by Walter B. Woodbury in 1866, which he followed up a few years later with the stannotype. By these inventions photo-engraving has become one of the fine arts. The system of letter press printing, by which an author's own manuscript may be printed from in his own chirography, is another application of the art of photography which is as marvelous as the Kinetoscope or the X-rays. This process is the invention of Mr. Friese-Greene, and was suggested to him while experimenting with another invention.

ELECTRICITY

Though the opinions of scientists vary in their estimate as to which is the greatest achievement of the Century, electricity is the foremost in the popular estimation. The reader of this book cannot but be impressed with the fact that electricity enters into all of the achievements of the Century. There is scarcely a branch of science and industry that is able to struggle along without its aid.

Yet though the Nineteenth Century has changed electricity from a philosopher's toy to man's most useful servant—and this change dates from the time of Volta's pile in 1800—still electricity is one of the oldest things of which we know. Electricity, like fire, was probably the discovery of primitive man. Humboldt tells us that the Indians of the Orinoco generate the electric current by rubbing certain beans together until they acquire the properties of a magnet. Thales of Miletus, who lived six hundred years before Christ and was the father of Greek philosophy believed that there was a soul in amber, which rubbed acted as a magnet. Thus we get our word "electric" from the Greek word "elektron," meaning amber. It was not until the Sixteenth Century that the name was given by Dr. Gilbert, who made the discovery that amber is not the only substance that gives forth electricity when rubbed and that all substances may be attracted. Otto von Gueriche, burgomaster of Magdeburg, found out that he could excite a considerable quantity of electricity by turning a ball of sulphur between the bare hands and Sir Isaac Newton, by a slight improvement on this method, was able to create sparks several inches long. These were the most

important discoveries in the field of electricity until the day of Franklin, when the American philosopher first put electricity to practical use in 1748 at a picnic by killing a turkey with the electric spark and roasting it by an electric jack before a fire kindled by means of a Leyden jar. But in these instances electricity did only that which could have been done as well and more economically by other means. Franklin announced his theory of a single fluid, terming vitreous electricity positive and resinous negative, in 1747, and in June, 1752, demonstrated the identity of the electric spark and lightning by drawing electricity from a cloud by a kite.

Such was the state of our knowledge of electricity in the very first year of the Century when Alexander Volta of Pavia, made public his device known as Volta's pile, from which have grown our present machines for the generation of electricity, though Volta's device was based upon Galvani's discovery. Galvani, a professor of anatomy in the University of Bologna, wished to tempt the appetite of his sick wife by making her some soup of frogs. He had skinned the batrachian and hung it on a copper hook so that, dangling, it hit an iron rail a little below. Galvani noticed that the casual contact caused a twitching in the dead frog's legs and in latter experiments produced the twitching by touching the nerve of the limb with a rod of zinc and the muscle with a rod of copper in contact with the zinc. The professor of anatomy thought that he had discovered the principle of life and built up on these experiments a theory that seems absurd now. He died in 1798 without knowing the renown that his frogs would win. Alessandra Volta, professor of physics in the University of Pavia, heard the story of the frogs and after investigation and experiment proved that the electricity was not in the animal, but was generated by the contact of

the two dissimilar metals and the moisture of the flesh. His pile, given to the world in 1800, is the prototype of the modern battery. He arranged a series of bits of copper and zinc alternately, one above the other, but each bit of metal separated from its neighbor by a piece of cloth wet with dilute acid. The more bits of metal there were the stronger the current which could be produced. Since the day of Volta the voltaic cell and galvanic battery have been greatly improved, yet they remain essentially the same in principle and therefore science gives to Volta the credit of having made the greatest force in nature serviceable to man. The electrician has been taught his business by the voltaic cell, even if the voltaic cell has been largely supplanted by other devices.

The next great step in the practical development of electricity was due to the discovery of H. C. Oersted, of Copenhagen, in 1819, of the action of the electric current on a magnetic needle and the relation between electricity and magnetism. Oersted found that if a magnet be moved near a piece of metal, preferably a coil of copper wire, a current of electricity is produced in the coil. Every electro-magnet illustrates this discovery of Oersted's. Until you bring it very near or make it touch a steel magnet it is simply a piece of soft iron; then, for an instant, as the core becomes magnetic you excite electricity in the wire surrounding the electro-magnet. You pay for that electric pulse in the forcible pull required to separate the electro-magnet and the steel magnet from each other. Replace this effort of the hand by the might of an engine with corresponding increase in the size and improvement in the form of the coil and your little experiment merges into building and driving a dynamo. Thus Oersted and his successors have made possible the dynamo.

Oersted's discovery owes much to the subsequent dis-

coveries of Ampere and Faraday. Ampere exhibited the action of the voltaic pile on the magnetic needle and that of the terrestrial magnetism on the voltaic current. He also arranged the conducting wire in the form of a helix or spiral, invented a galvanometer and imitated the magnet by a spiral galvanic wire, in 1820. Two years later Faraday, who was a shop-assistant to Sir Humphrey Davy, explained electro-magnetic rotation. Working upon the discoveries of Oersted and Ampere he announced his discovery of induction which was announced in a series of papers read before the Royal Society of London. Faraday not only proved Oersted's investigation, but discovered magneto-electricity, its converse, by producing an electric spark by suddenly separating a coiled keeper from a permanent magnet and found an electric current in a copper disk rotated between the poles of a magnet. His brilliant experiments proved that the current developed by induction is the same in all its qualities with that of other currents and he demonstrated Franklin's theory that all electricity is the same; that there is but one kind.

Upon induction and its laws for the explanation of the principles of which we are indebted chiefly to Faraday, depend the simplest as well as the most complicated of our modern electrical appliances for a reason of action. Briefly explained, induction is the action which electrified bodies exert at a distance in a natural state. Faraday's and Ampere's spiral were the forerunners of the electric coil, which consists of two separate coils of insulated wire wound around a soft-iron core.

To give the barest summary of the developments step by step since that time would fill a volume, and so there is not space to allude to them here. The development of the telephone, telegraph and electric-light are sketched in other chapters, while many applications of electricity fall

most naturally under the industry to which they are applied. Here will be given some account of the development of the electric motor and dynamo, together with the transmission of power and novel applications of electricity which do not fall properly under other divisions of this volume.

The germ of the electric motor is found in the invention of Joseph Henry, an American, who, though little known to the public, was one of the most prolific electrical inventors the world has seen. Many improvements were made by him in the magnet. Exhaustive research was made by him into the subject of the battery as a source of energy and the efficiency of the galvanic batteries, and in 1831 he constructed an electric motor, the first of the kind the world had ever known. In Henry's machine the current was actuated by a voltaic battery, but in the middle of the Century Moritz H. Jacobi, a German, found that a dynamo-electric machine can also work as a motor and that by coupling two dynamos in one circuit—one as a generator and the other as a motor—it was possible to transmit mechanical power by electricity. But how late a development the dynamo really is, can best be understood by the fact that the word is not mentioned in the latest English edition of the Encyclopædia Britannica—the editions without the American supplement. There is some mention, however, of the magneto-electric machine of Gramme, made in 1870, which was the first to practically transmit power in the fashion in which it is used in nearly every town and civilized country today. During the past generation electricity has come to be universally recognized as the best way for the transmission of power, distributing steam, wind or water so as to bear upon any point desired. The most familiar application of this process is the electric light and the trolley line. Perhaps the

first application of the electric motor, however, was about 1839, when Jacobi sailed an electric boat on the Neva with an electro-magnetic engine of one horse-power.

It is the dynamo, however, that has made possible the use of electricity for power. Cheapness is the factor that has led to this result, for the chemical way of obtaining electricity by the action of acids upon zinc was so costly that few people dreamed thirty years ago that electricity would ever become a rival to steam as a source of motive power. The first use of the word "Dynamo" was made by Siemens, who called his machine "dynamo-electric"—the word dynamo being Greek for to be able—and this expression contracted to the single word dynamo has since been universally employed. The modifications of the forms of and arrangements of the different dynamos that have been invented in recent years are endless, and every week new patents are granted for improvements to parts. On this account we shall not trace the history of the dynamo in great detail, nor shall we point out the difference between the various types. Instead, we shall briefly sketch a type of the dynamo as it is today, which will give the general principles of its action.

Originally the dynamo was a horseshoe magnet set on a shaft and made to revolve in front of two cores of soft iron wound round with wire and having their ends opposite the legs of a magnet. Then the magnet no longer was made to turn on a shaft, but on the lighter iron cores, and so today the huge field magnets of a modern dynamo are not made to turn around a stationary armature, but the armature is whirled around within the legs of the magnet with great rapidity. The number of magnets was increased, as was the number of wire-wound cores, while the magnets were gradually made compound, laminated. Siemens, of Berlin, in 1857, wound the iron core length-

wise, with wire instead of round and round a spool, and then the shaft of the armature was placed cross-wise between the legs of the magnet, as in the modern dynamo. One of the ends of the wire used in this winding was fastened to the axle of the armature and the other to a ring insulated from the shaft, but turning with it. The current was carried away by wires attached to two springs, one bearing on the shaft and another on the ring. Siemens also originated the mechanical idea of hollowing out the legs of the magnet on the inside for the armature to turn in, close to the magnet, making it almost fit.

Alternating currents resulting because of induction, the commutator was then devised to cause the currents to flow in the same direction. The springs known as brushes were so arranged that their alternate action made the current carried away always direct. A machine in which a ring armature is used, doing away with the commutator, was then constructed by Pacinotti, of Florence, and it is extensively used for certain purposes.

The huge field magnet, which is really not a magnet at all, was made possible by the improvements of Wilde, of England, in 1866. He caused the current, after it had been rectified by the commutator, to return again to the coils of wire round the legs of his field magnets. This induced in them a new supply of magnetism and intensified the current from the armature. Step by step minor improvements followed, each inventor contributing his part to the perfection of the magnificent machine as we have it today. The machines are of various types and seem capable of but little further improvement, as there are dynamos in use to-day which give 92 per cent of a possible 100 per cent of their engine power. The engine which turns the dynamo, however, still wastes at least 90 per cent of the furnace heat.

The motor is the twin of the dynamo. If a dynamo instead of being driven by an engine and used to give a current, has a current from a separate source (as from another dynamo or from a battery) passed through it, its armature will revolve and the dynamo become a kind of electric engine capable of driving machinery. A dynamo when used in this manner is called an electro-motor or simply a motor. The difference between a motor and a dynamo has been well summarized in these words: It is the work of the dynamo to convert mechanical energy into the form of electrical energy; the motor in turn changes this electrical energy back again into mechanical energy.

No motor intervenes where the electric light is produced by the dynamo current. Some restriction upon the current converts the current into heat and light. The motor is always the intermediate machine when mechanical movements are to be produced by the current from the dynamo. The armature of the dynamo, rotated by steam or water power, produces electrical energy in the form of a mighty current, and this is transmitted over a wire. This current, reaching the motor, rotates the armature.

A new day has dawned in the workshop and factory by the introduction of the dynamo and electric motor. Availing himself of the fact that electricity is able to transmit power without any movement by the wire, the wilderness of whirling wheels and belts has been removed from the shops and a few wires have taken their place, each entering the electric motor which drives the separate machine. The result is often an enormous saving of power that is required when steam or water is used direct to keep the multitude of needless pulleys and belts going. It was found once at the Waltham watch factory that three-quarters of the engine-power was absorbed by shafts and gearing without a single machine's being harnessed for duty.

And where one machine among many is to be set at work by itself, especially at a distance from the engine, the loss in the mechanical conveyance of power becomes inordinate, while the loss is almost entirely avoided by electrical transmission. The decrease in the weight of machinery and in vibration makes it possible to build the factory with thinner walls and to keep it cleaner and neater at all times.

A great step was made in the increased utilization of electricity when the problem of the transmission of power over long distances was solved. Now a current can not only be distributed through a workshop with the utmost convenience and economy, but it can be sent to a workshop from an engine or waterwheel many miles away. The Niagara Falls is yoked to the wheels and lamps of Buffalo. This in itself is typical of all the achievement of the Century, and is the crowning glory of electrical development.

The first experiments in this direction were made by Marcel Deprez at Creil in 1876 to 1886, and Deprez succeeded in transmitting mechanical power thirty-five miles for industrial purposes in the latter year. Many inventors busied themselves along these lines, and on February 3, 1892, Nikola Tesla, at the Royal Institution, exhibited his alternate-current motor, by which currents are transformed, by continually reversing the direction, into mechanical power. By means of Tesla's apparatus the force of 77 horse-power was transmitted from the rapids of the Neckar to Frankfort-on-Maine, 110 miles, September, 1891.

Possibilities of the utilization of waterfalls for the transmission of power electrically immediately attracted attention to the world's greatest waterfall, that of Niagara. At Niagara River and Falls, about 18,000,000 cubic feet of water flow per minute through a descent of more than

300 feet, including both falls and rapids; this represents something like 7,000,000 horse-power. Engineers had been aware that the enormous power which goes to waste over the Niagara was sufficient to turn the wheels of every factory in the United States, but there seemed to be no possibility of its utilization. While a few paper mills and flour mills had been established near there, the expense of the direct application of the power was too great to make the attempt desirable. But when dynamos had been perfected and electricity made commercially available, attention became attracted to the waste of power. Siemens, the great German inventor, in 1877 prophesied that a few more years would see the great water-courses like that of Niagara utilized in part to generate electricity and to transmit by its means electric light and power to surrounding industrial stations. It seemed a wild dream then, but before twenty years had passed it had been realized, and today the power of Niagara is turning machinery and running street cars in Buffalo, twenty-six miles away. Power from the falls has been used to operate machinery in New York, being thus employed at the electrical exposition.

When a waterfall is to be used for power the ordinary method is to dig a canal from a point above to a point below the waterfall, this canal being called a mill-race. The water in this canal is so directed as either to fall upon or to flow under a wheel, and the revolution of this wheel furnishes the motive power of the mill with whose machinery it is connected, by means of shafts and belts. Æsthetic reasons alone would have prevented the employment of these means at Niagara, and would merely have resulted in building a canal which would be lined with mills. An entirely different method was proposed by Thomas Evershed, state engineer of New York, and his

suggestion was adopted by the company. At a point about a mile above the falls, 1,200 acres of land were bought, and here a short canal was dug and an enormous pit, 140 feet in length, 18 feet in width and 178 feet deep was excavated. From the bottom of this pit a tunnel was also made to the river tunnel level some distance below the falls. This tunnel is 6,807 feet (over a mile and a quarter) in length, and it took a thousand men more than three years to dig it, even with the improved tunneling appliances of this generation. Enough limestone rock was dug out of the tunnel to make some twenty acres of new land worth $5,000 an acre along the shore of the Niagara, and the construction of the tunnel and mainwheel pits cost twenty-seven lives. The tunnel is shaped like a horseshoe, being 18 feet 10 inches wide at its broadest part and 14 feet wide at the bottom. It is 21 feet high and has a downward pitch varying from 4 to 7 feet in 1,000. It is lined at the lower end with heavy steel plates, and the rest of the way with from four to six rings of brick, especially prepared to withstand the wear and tear of water for generations to come.

This tunnel is the "tail-race," as the millwright would call it. The water drawn from it, falls a distance of 154 feet to the bottom, where, by its fall, it may revolve ten enormous horizontal or turbine wheels. These in turn may revolve ten dynamos in the power-house above, each capable of furnishing 5,000 horse-power—only three of these turbines have as yet been built. The water having thus given its power to the company, which has transferred it into electricity, runs off through the tunnel and is discharged into the river below.

So far as the producing of water power is concerned, the only novel feature of the plan in operation at Niagara is the enormous size of the plant.

The turbine wheels, placed at the bottom of that mighty pit cut straight down for 200 feet into the solid rocks, are the monarchs of their kind. The force of the volume of water that each of the three now in place receives is so great that it would sweep away a considerable structure made as strong as man could build it with stone and masonry. Yet these turbines are so cunningly devised, and with such tough mingling of the strongest metals, that they will receive this prodigious blow only to turn with almost incredible swiftness upon their axles and thus communicate the force to the dynamos placed in position directly over them, although two hundred feet above. The dynamos are fitting mates for these mighty machines at the bottom of the pit, for they are not only said to be the largest of their kind, but they will, with the swiftness of the lightning's stroke, convert the force created by the water power upon the distant turbines.

The size of these turbines and dynamos will be better appreciated by comparison. The largest turbines ever constructed before these were built were of 1,100 horse-power each, and the largest dynamo was said to be that which generated 2,100 horse-power in the Intramural Electric Railway's power-house at the World's Columbian Exposition.

The armature of the dynamo is set so that its axis is perpendicular instead of horizontal, and with its cover it surmounts the pit like a huge cap. In front of each dynamo, stands a governor, an interesting and complicated mechanism in itself, which controls the movement of the big cylinder. Behind the dynamos, on a raised platform in the center of the dynamo room is the switchboard arrangement, where the mighty current from these great machines is received and sent out in whatever direction it may be required.

In generating the current use is made of what is called the Tesla polyphase alternating current system. Each generator delivers an alternating current to each of the two circuits. Being 180 degrees apart, each current attains its maximum when the other is at zero, and 3,000 times each minute the current is reversed. Heavy insulated cables convey the current thus produced to the switchboard, where other heavy lead-covered cables carry the current through a subway to the transforming house, a small structure on the other side of the canal. Wires intended for nearby consumers enter the conduit here, but the current for use in Buffalo is converted into one of 11,000 voltage for transmission and is ready for its journey.

Heavy wires of bare copper strung on poles, with porcelain as insulators, transport the current to Buffalo. When the current reaches Buffalo it is again passed through transformers which lower the pressure to 370 volts. As the current at present is used to operate street railways it must be changed from alternating to direct currents. Machines, known as rotary converters, are employed for this work, and they change the 370 volts alternating current to 500 volts direct current, and it is then ready to operate the cars.

While the plant of the Niagara Falls Power Company was completed on March 23, 1895, the power was not used in Buffalo until November 16, 1896, when the company began the supplying of 1,000 horse-power of electrical energy for the running of the street railways in Buffalo; and now the citizen of Buffalo, gazing at the great falls, can realize the fact that it is the slave that carries him in his journeys about the city.

In time it is expected that the power at Niagara can be used to run machinery in New York and Chicago.

Nikola Tesla, whose polyphase alternating current system made possible the transmission for twenty-six miles, is at work about the problem, and there is every possibility of its success. For the present it has been shown that power may be transported from Niagara Falls to New York; for in May, 1896, about one-thirtieth of a horse-power was transmitted to the Electrical Exposition in New York City, the current being used to operate a two-phase alternating current motor, which operated a working model of the Niagara Falls Power Company's plant. The current was carried on two of the Western Union Telegraph Company's wires. This is the longest distance that an electrical current has ever been transmitted. The waste of the current makes its use on an extensive scale impractical, but the problem will be solved in the near future, in the opinion of all electricians. And when that time comes the whole of Niagara's great power may be utilized. What the use of this 7,000,000 horse-power will mean is told in a striking manner by C. F. Scott, of the Westinghouse Company. He says:

"Suppose pumps be placed below the fall for pumping the water up again to its former level. If a man exerts a force of about twenty pounds per stroke and works at a fair rate for eight hours per day, it would take about ten times the total population of the United States to pump the water back as fast as it is flowing over the falls. Consider for a moment what that means. If 70,000,000 of us were engaged in manual labor, all the work that we could do could be accomplished ten times over by the power now going to waste. All the work of laborers; all our actual exertions in digging, hammering, lifting, climbing stairs, running sewing machines, or riding bicycles, do not represent the one-hundredth part of this stupendous power."

Long-distance transmission of power is not confined to Niagara Falls. The water-courses of the United States are rapidly being made use of in this manner. The state in which are the largest number of long-distance transmission plants is California, which is especially favored by its natural topography for the development of electricity by water power. At Bodie, Cal., the current is transmitted thirty miles, and at Sacramento, Cal., 3,000 horse-power is transmitted twenty miles.

Utilization of water-power on a small scale, as well as by taking advantage of the greater waterfalls, has made possible a vast increase in the use of electric power. Electricity is now being developed from water power as cheaply as steam power can be made from coal. Sometimes it is cheaper, and wherever the cost is about the same, the cleanliness of electricity and the absence of pulleys make it favored. There is also the advantage that the difference in first cost is in favor of electricity when the power is rented. In large cities and many towns electricity is therefore coming in greater use for running machinery. It is used to a great extent for traveling cranes, derricks and other heavy machinery. Most of the big newspapers and other establishments, where there is no necessity for a foundry, are gradually adopting electricity. Another application that is quite common is to electric elevators. It is said that in New York and Chicago as many people travel perpendicularly as travel horizontally; and however this may be, the elevator industry is very large, and electricity has become the favorite method of propelling elevators—so general, in fact, that it seems almost incredible that the very first use of electric current for power purposes was upon a freight elevator in New York in 1882.

The problem of the electrician now is to obtain elec-

tricity direct from coal. While the dynamos of the best design give forth in the form of electricity 92 per cent of their engine's power, yet the engine which turns the dynamo wastes, as has been said, at best 90 per cent of the furnace heat, and does little better when steam is used without the intervention of the dynamo. Although great increase has been made in the obtaining of larger energy from steam-engines, it seems possible that but little further progress can be made in this direction, and electricians look to electricity as the method by means of which all, or the greater part, of the energy stored in coal may be conserved. The problem is being attacked from two sides one the thermo-electric on the principle of the thermo-electric couple. Edison has made some experiments, and one apparatus devised by him had as its operative feature the magnetization and demagnetization of iron by rapid alternations of temperature. Tesla is reported to have nearly perfected an invention along these lines, but he is not likely to make it public until it is ready for use. From the chemical side the problem has been attacked by Dr. W. Borchers, of Duisburg, Germany, who in a paper read before the German Electro-Chemical Society, announced that the problem of cold combustion of the gaseous products of coal and oil in a gas battery, and its direct conversion into electrical energy, can certainly be solved. The brains of many electricians are busy with these ideas, and there is a possibility that a few years may see the utilization of coal without the wasteful intervention of the steam engine.

Tesla's oscillator, which was exhibited at the World's Columbian Exposition, is a step in this direction. It makes the steam-cylinder operate the dynamo without the intervention of any other mechanism. The one exhibited was merely a steam chest, disassociated from the usual

governing mechanism, that thrusts armatures into the fields of a force of an electro-magnetic coil. The invention is as yet in an imperfect state.

The storage battery—miscalled, for it is really not an attempt to store electricity—is as yet in its infancy. It is really a secondary battery, the principle of its action being the decomposing of combined chemicals, by the action of a current applied from a stationary generator or dynamo, and these currents again unite as soon as they are allowed to do so by the completing of a circuit, and in recombining give off nearly as much electricity as was first used in separating them. Leaden plates, one cleaned and the other fouled by the action of a current, are the basis of the secondary battery. The expense and inconvenience of the arrangement has prevented its wide utilization, although it is used on some street railway lines and as a means of propulsion for motor carriages.

Electricity has been put to a number of minor uses. The electric bell, now in common use, was invented by John Mirand in 1850. On pressing a button, spring contact is made and the current flowing through the circuit strikes the bell. It has been improved so that the bells are serviceable as alarms in many ways. An undue rise in temperature may melt a piece of fusible metal and warn the proprietor of fire. Safes and show-cases as well as doors may be made to signal by a red light the fact that they have been burglarized. A thief was once photographed by a flashlight kindled in this way, and the likeness thus secured brought about his capture. The announcing of the entry of burglars into a house is of course an easy matter.

Electric clocks are familiar in every city or large town. Electric magnets are placed behind the dials, and, by means of an armature working at a frame and ratchet wheel as

the current is sent from the standard clock, move the hands forward every minute or half minute.

The phonograph, which is startling, but has not as yet been made of great commercial use, is one of the most interesting of electrical devices, as it stores and reproduces speech. Edison announced his invention in 1878, and the instrument succeeded so well that a member of the Academy of Sciences at Paris declared that it was a mere ventriloquist's trick. The phonograph, as perfected, is simple in its construction. Every vibration of the diaphragm causes a stylus at its end to make a corresponding mark on a cylinder which is set in operation. After the record is made the sounds are reproduced as the stylus again travels over the indentions. Aside from its use as an amusement, the phonograph is chiefly useful as a means of dictation, the words being repeated in the ear of a typewriter operator at whatever speed may be desired. It is also used to teach pronunciation, and will be invaluable in preserving exact records of the speech of the present and the voices of great singers for future ages.

So many and varied are the uses of electricity that it enters into every science, and many of these applications are mentioned in this volume under the heads of those general subjects. To barely enumerate these devices would require a volume. The induction balance has been used as a sonometer, or machine for measuring hearing, and the bottom of the sea has been explored by sonometers for sunken treasure. Leaks in water-pipes have been localized by the microphone, and the story is told of a Russian woman who was saved from premature burial because the microphone made audible her feeble heartbeats. The peculiar sensitiveness of electricity makes it a means of surpassing delicacy in measuring heat, light or chemical action. By the bolometer, invented by Prof.

S. P. Langley, a change of temperature of one-millionth of a degree Fahrenheit has been recorded, a refinement scarcely approached by any other means of scientific detection.

The automatic devices are endless. It is used for every purpose, and indeed the system of electrocution made use of in New York as a means of capital punishment makes it possible for a man to die by electricity as well as to live with its aid.

It is said that while much progress has been made during the Century in the application of electricity, men are still ignorant as to what it is. As a matter of fact, the principles of electric action are known. We know that electricity will induce magnetic force and magnetic force will generate electricity; that electricity will induce chemical action and chemical action will induce electricity; that electricity will generate heat and heat will generate electricity; that electricity will develop light and light will generate electricity. We also know the conditions under which these actions take place and the relations between the cause and effect.

Because man does not know why electricity will make a motor revolve and give off power, he thinks we do not know much about electricity. It is possible to know what a natural phenomenon will do, and yet not know what it is. Consider for an instant the steam engine, and if you trace back to the primary cause of its motion you will find that we know nothing of the true nature of that cause. We know that heat gives steam an expansive force, but we do not know why. No one knows why heat expands matter. Although there are theories, no one knows what heat is.

So physicists, during the Century, have found out what electricity is, just as they have found out what sound, heat

and light are. They are alike in some respects. They are all vibrations of that subtle and all-pervading medium which pervades the universe and is known as the ether. Young and Fresnel have shown that space is filled with luminiferous ether of which very little is known except the mathematical conditions under which waves are propagated in it. Clark-Maxwell, by the extension of the mathematical theory of light, has shown that light and electricity are of exactly the same nature, and Hertz, the German physicist, by his experiments, demonstrated the truth of this, independently of mathematical theory. Light and electric vibration have been shown to be one and the same thing, differing only in the lengths of the vibrations. The reason why we do not wonder what light, heat and sound are is not that we know, but that we are so familiar with them from our birth that we do not stop to wonder. We know what electricity is in the sense that we know what light, heat, and sound are, and in that respect only.

MINING AND METALLURGY

Mining and metallurgy are not devices of the Nineteenth Century; for Tubal Cain is mentioned in Genesis as a worker in metals, and ever since then men have dug minerals from the earth and fashioned them to their uses. Yet because of improved methods in digging out subterranean treasures and extracting the ores, the industries of mining and metallurgy have had a phenomenal growth during the past hundred years. While agriculture has only doubled and manufactures quadrupled since 1840, the mining output has increased thirteen-fold. The increase since 1840 is shown by the following table, compiled by the statistician Mulhall:

	Hands.	Tons raised.	Value.
1840	442,000	56,200,000	$ 157,500,000
1860	1,016,000	182,600,000	380,000,000
1880	1,760,000	420,400,000	745,000,000
1894	3,130,000	746,000,000	1,510,000,000

These statistics show that, although mines are deeper, one man now raises as much weight in mineral wealth to the surface of the earth as two did fifty years ago. It is worth mentioning that the United States mines about one-third, Great Britain one-third, and the rest of the world combined the other third in quantity, while in value the United States is far ahead.

Seventy per cent of the total weight of minerals mined is coal, and so in a review of the gigantic and marvelous developments that have taken place in mining and metallurgy during the Century just closing, too much importance cannot be attached to that mineral, as the chrysalis of

latent energy, as the one great omnipotent factor of all modern industrial evolution. Indeed, so all-essential has coal become to civilization, that man dare not even in fancy conceive of a time when it shall have become exhausted. Yet the geologist and the statistician have logically demonstrated that at the present rate of consumption the coal supply of the entire world will have been consumed within one thousand years. In answer to the question that naturally arises, What then? scientists, philosophers and magicians are all mute; for, so far as they are now able to see, all their vaunted triumphs will be as naught on that fatal day, and the wheels of progress forever cease to turn.

Yet the grimy black substance which we have come to regard as an absolute necessity to our very existence, was practically unknown to our forefathers except as an obnoxious and unwelcome substitute for fire-wood. The opening of the present century found the world in comparative ignorance of its industrial value.

The first authentic mention made of coal in history is by Theophrastus, about 300 B. C., although it is probable that its combustible qualities were discovered long before that. It was mined by the men of the paleolithic and neolithic ages, as we know from the flint axes and other implements found in prehistoric excavations in various parts of England. It is possible that the early Britons were slightly acquainted with its industrial value at the time of the Roman invasion in 55 B. C. In 1239 a charter was granted the freemen of Newcastle, giving them permission to dig and gather coal in the Castle fields, and here the history of coal as a commercial product may be said to have begun. When Newcastle coal was offered for sale in London it was indignantly rejected by the city fathers as an innovation inimical to the health and happiness of the city, and it was not until after much persua-

sion that permission was given to unload it. In 1300 a proclamation was issued by the King, prohibiting its use within the city walls, and imposing a fine upon those who persisted in burning it. The license granted the freemen of Newcastle was revoked, and the coal question was supposed to have been settled forever. During the reign of Edward III, the prohibitive law was repealed and the Newcastle freemen were again allowed to dig and gather coals and ship them to London. During the reign of Elizabeth its use was again prohibited in London during the sitting of parliament, as it was claimed to be injurious to the health of the country squires during their sojourn in the city. But notwithstanding the many obstacles placed in the course of its progress, the use of coal spread rapidly, and the middle of the last Century found it used almost exclusively in the smelting of iron and for other industrial purposes all over England.

Although the early history of coal is thus distinctly linked with the history of England, its later history is common to nearly all the great nations of the world.

The first discovery of coal in America was made at Ottawa, Illinois, as is chronicled by Father Hennepin, a Jesuit explorer, who visited that section in 1679. The first coal mine was excavated near Richmond, Virginia, the discovery having been made by a small boy while fishing on the James River, the bituminous vein being exposed along the shores of the stream. Ten years later the famous strata of bituminous coal was discovered around Pittsburg, and at the beginning of the Nineteenth Century shipments were made to Philadelphia. Anthracite coal was discovered by a hunter, Nicho Allen, near Wilkesbarre, Pa., in 1792. Like many other important discoveries, it was accidental. Allen encamped one night and built his fire upon some small black stones that lay scat-

THE ROLLING MILL

Painting by A. Menzel

NOTICE.

HOW TO OPEN A BOOK.

From "Modern Bookbinding."

Hold the book with its back on a smooth or covered table; let the front board down, then the other, holding the leaves in one hand while you open a few leaves at the back, then a few at the front, and so on, alternately opening back and front, gently pressing open the sections till you reach the center of the volume. Do this two or three times and you will obtain the best results. Open the volume violently or carelessly in any one place and you will likely break the back and cause a start in the leaves. Never force the back of the book.

"A connoisseur many years ago, an excellent customer of mine, who thought he knew perfectly how to handle books, came into my office when I had an expensive binding just brought from the bindery ready to be sent home; he, before my eyes, took hold of the volume and tightly holding the leaves in each hand, instead of allowing them free play, violently opened it in the center and exclaimed: 'How beautifully your bindings open!' I almost fainted. He had broken the back of the volume and it had to be rebound."

tered about in profusion. Having cooked his supper, he went to sleep as usual, and when he awoke in the middle of the night he found himself lying in a bed of flames. The stones were all on fire, and he barely escaped with his life. He told the story of his adventure far and wide, and shortly afterwards a company was organized to mine and ship the black stones to Philadelphia. Colonel Shoemaker, a worthy colonial gentleman, was at the head of the enterprise, and upon his recommendation most of the first consignment was sold. The people, however, did not understand how to use the coal, and there was a popular feeling of indignation against Colonel Shoemaker, who was denounced by the city authorities as a rascal for having palmed off rocks upon them as coal. Since then Philadelphia has grown to be a great city largely through the agency of those same black rocks, and the anthracite coal fields of Pennsylvania yield 50,000,000 tons annually.

It would be hard to estimate the amount of money the United States has made out of its coal. One small region in Eastern Pennsylvania produces every year coal to a greater value than all the gold mines of the Rockies, Canada and Alaska. Adding to this the value of our annual production of a hundred and thirty odd million tons of bituminous coal, it can be said safely that we get more than three times as much wealth out of our coal mines as out of our gold mines. The great Appalachian field produces 100,000,000 tons annually. Indiana, Kentucky and Illinois have an immense output. Utah, Montana, Colorado, Washington and Wyoming are also rich in coal deposits, and fields of incalculable value have been in late years discovered in Alaska. There is scarcely a country on earth where coal has not been discovered in greater or less quantities. The following table is the latest estimate (1897) of geologists regarding the world's coal produc-

ing territory: China, 200,000 square miles; United States, east of the Rockies, 192,000 square miles; Canada, 65,000; India, 35,000; New South Wales, 24,000; Russia, 20,000; United Kingdom, 11,500; Spain, 5,500; Japan, 5,000; France, 2,080; Austria-Hungary, 1,790; Germany, 1,770; Belgium, 510.

Although the English coal area is comparatively small, nevertheless that country was for years the center of the coal production of the world, and for many years mined more than half the total amount used by the world. But her coal production is being gradually overshadowed by that of the United States. The English coal veins are shallow. The Newcastle coal fields, her richest, have veins from three to six feet thick, while the Pennsylvania anthracite veins run from thirty to sixty feet in thickness, and the Pittsburg bituminous veins from ten to sixteen feet. Some of the English veins are already worked down 3,887 feet, and at the present rate of mining it is estimated that if it is worked down to 4,000 feet English coal will be exhausted in about 200 years. It is therefore possible that England's glory as a manufacturing nation must soon be on the wane. It is also self-evident that the United States, with its vast supplies of that mineral, and its magnificent facilities for transportation, already the chief manufacturing nation of the world, is destined to increase its lead enormously. The coal mining systems perfected during the present Century, and their equipments of colossal machinery are among the wonders of the engineering and mechanical world. The modern coal mine of a large scale is really an underground city with avenues and streets extending for many miles. One of the largest of these subterranean towns is near Newcastle, England, and contains not less than fifty miles of passages, the result of excavations wrought by human hands.

The mode of working the coal mines has undergone a complete revolution. The older process was, after reaching the strata to be operated, to take out as much of the material in stalls as was considered safe. This left a pillar to support the roof of the mine, and thus only a portion of the material was available. In 1816, by the introduction of the Davy Safety lamp, it was rendered possible to work in what were very dangerous circumstances, and less and less wall was left in the form of pillars. This was called the "long wall working," and is the method in use at the present day. The system consists in the excavating first of long roadways through the strata, the superincumbent strata sinking down on the top of the wastes left behind by the miners.

The ventilation of mines had long engrossed the attention of engineers and legislatures. The first radical improvement brought about in this direction occurred in the year 1820, when the workings were divided into distinct portions or panels so as to insure a direct passage of air from the downcast to the upcast shaft. These shafts are, in reality, very deep wells sunk at either end of the mine. The air from the downcast rushes through the passage and seeks egress by way of the upcast. The draught of air thus created, while it carried away a certain amount of impurities, was insufficient to provide air for inhalation by the army of workers. To accomplish this a large furnace was placed at the foot of the upcast shaft. the intense heat arising from this furnace rarified the column of foul air admitted above it, thus causing it to ascend and make room for the colder air from the downcast shaft. For many years this method was without a rival. Various pumps, fans and pneumatic screws were tried without success. But in 1849 an English mine owner named Powell put into his mine a large centrifugal fan,

designed by Brunton. It operated on a vertical axis and was placed at the surface. Although it was a marked improvement on the old furnace system, the new ventilator made slow progress until Guibal introduced another large fan at the London Exhibition. Since then the many advantages to be derived from mechanical means of ventilation at the surface have become more fully recognized, and fans, some of which run at terrific speed, are in use at all modern collieries.

The haulage of coal from the diggings through the devious passages to the foot of the mine shaft is another item in coal mining which has been greatly improved. The use of cast iron tramways dates back to 1767, and about 1820 George Stephenson introduced mechanical haulage underground, although its success was not ultimate until the use of wire ropes became general. Until 1845, or thereabouts, the underground haulage was accomplished chiefly by women and children, who were treated by their overseers as veritable beasts of burden. The passage of legislative acts about this time compelled proprietors to use ponies and horses underground. For many years chains and ropes were used for mechanical hauling and winding, a practice which entailed great danger—so much so that the chains had to be abandoned altogether. Until the year 1862 flat hempen ropes were used exclusively. Then Newell brought his metallic wire ropes to such a state of perfection that they were substituted for the hempen ones. Up to the present day the steel rope is without a rival, and it has done much to make mechanical haulage both possible and general. The rope is usually driven by an engine at the surface, but sometimes the engine is placed underground and run by steam or compressed air. The speed of hoisting or winding, as it is termed, compares favorably with that of railway trains.

At many of the large mines the coal is lifted a depth of half a mile in less than a minute. Owing to greatly improved appliances in shaft machinery accidents are very rare. In the best regulated coal mines there are automatic appliances, in case of the cage becoming liberated from the rope, to prevent its falling down the shaft again.

The greatest danger to which the coal miner's life is, and always has been, exposed is that which awaits him in the form of explosions of inflammable gases. In the early years of the Century these explosions received the attention of all the leading scientists. Until the introduction of Sir Humphrey Davy's safety lamp in 1816, coal mines were tested before the men entered them by "trying the candle;" the presence of the deadly fire-damp being shown by the flame assuming a bluish color, and other gases by various peculiarities in the tint and shape of the flame. Complicated improvements which have since been made on the Davy lamp, together with the introduction of electric light wherever available, have in recent years combined to reduce this danger to a minimum.

Next to coal, iron has been the greatest factor in the phenomenal industrial progress attained by the genius and wisdom of the Nineteenth Century. The history of iron and the manufacture and use of steel are as old as civilization itself. The Chinese were familiar with steel fully 2600 B.C., ancient Chinese writings containing descriptions of the processes used in its conversion. The Phœnicians were also acquainted with the use of extremely hardened iron (properly speaking, steel) as their numerous and beautiful works in ornamental metallurgy, and the cutting and engraving of precious stones, for which they were conspicuous among the nations of antiquity, necessarily involved. During the Middle Ages the strength and durability of iron led to its extensive manu-

facture and use for defensive purposes, and the iron-monger and blacksmith occupied prominent positions among the craftsmen of that darkened period of the world's history.

Crude cast or "Pig" iron is the most widely used metal of modern times and the most indispensable in the industrial arts, either as the material out of which articles may be formed by the operation of casting, or as the substance from which the purer forms of the metal may be obtained.

The history of the metallurgy of iron and steel during the present Century is marked by four epoch-making inventions, beside which all others sink into comparative obscurity. These four inventions, which completely revolutionized the industry to which they were applied, are: The hot blast for blast furnaces, invented by James Neilson in 1828, which doubled the output of the blast furnace without any extra fuel; the Bessemer process for the conversion of steel, invented in 1856; the Siemens regenerating furnace in 1862; and the Gilchrist-Thomas or basic process of making steel from iron containing phosphorus, invented in 1880. In following the development of the iron industry it is well to remember that the blast furnace producing cast iron has two offices to perform. It has to reduce the ore to a state of metal, which process is effected in the central and upper part of the furnace by the action of carbon and carbonic monoxide. The reduced metal is then melted, and in this operation it absorbs carbon and becomes cast iron, while the foreign matters of the ore fuse with the coke-ash and are withdrawn in the form of slag.

The very early iron furnaces did not produce cast iron, unless by accident; they produced a steely wrought iron that did not melt, but had to be picked out of the furnace. This was due to the fact that the furnaces, being very

small, used charcoal as fuel, which had great power of reduction, but would not make sufficient heat to melt the iron. In 1828 Neilson conceived the idea of feeding all kinds of furnaces with blasts of hot air. The invention proved a great success and effected a great saving in fuel, with a phenomenal increase in the production of the English furnaces. No further notable improvements were made until 1845, when Budd conceived the idea of utilizing the gas which escaped from the mouth of the furnace by drawing it below and heating the air for the hot blast with it. Soon after this the closed top to the furnace was invented.

With the exception of some special processes, entailing endless toil and great expense, the majority of steel in early days was converted from cast iron by the puddling process. This consisted in melting the cast iron in the form of pigs on the hearth of a reverbatory furnace, in contact with iron cinder and iron ore, accompanied by a constant stirring of the melted metal, or "puddling" as it is termed. After being worked into shape by hammers and rolls it was enclosed in cases of horn shavings and heated to a high temperature for many hours. When removed from the casing the metal showed a blistered surface, and was called blister steel. Puddling in this fashion necessarily involved a great amount of hard manual labor, and various attempts were made to get rid of it. Many minor inventions were made for the production of steel before the great revolutionary one of Sir Henry Bessemer put in its appearance in 1856. This is regarded one of the greatest inventions the world has ever seen, and has done more than almost anything else to revolutionize industry. Bessemer began his experiments in the production of steel from pig iron by use of the air blast. Cast iron was melted in a reverbatory furnace, from which it ran into

a vessel in whose bottom were a number of blow holes through which a blast of air was maintained. As the hot iron ran into the vessel, and as the blast was forced through it, its carbon and silicon were burned out and such combustion taking place heated the iron to an exceedingly high temperature. It was originally intended to withdraw the metal when the carbon was sufficiently reduced. But this was impracticable, except in rare cases, as the least trace of phosphorus impaired the quality of the steel. The system of blowing the metal to the complete exhaustion of the carbon, and afterwards adding a certain quantity of cast iron, was generally adopted. By varying the proportion of the materials added, it was possible to produce steel of any required percentage of carbon. Shortly after it was introduced into this country, Holley developed a system of hydraulic machinery for the operation of the process. The metal is now treated in an egg-shaped converter, mounted on trunnions, and large enough to treat at once from one to twenty tons of melted iron. It is automatically turned on its side to receive the charge, the blast is turned on and it is brought in an upright position to receive the blow. As the air passes through the melted mass, a vivid flame bursts from its mouth. The carbon and silicon having been burned out, the converter is turned again on its side to receive the carbonizing charge of ferromanganese or spiegeleisen, and the effect of any trace of phosphorus is partly overcome by the manganese thus added. The steel, which has been reduced to the consistency of water by the intense heat, is poured from the converter into moulds. Under the old steel processes these units were of but a few pounds weight, whereas the Bessemer process converts the steel into units of many tons. But thus far steel could only be made out of very pure iron, the presence of any considerable trace of phos-

phorus being ruinous. In 1878 Sidney Gilchrist Thomas announced that he had succeeded in reducing the phosphorus in the Bessemer process by the use of lime. After exhaustive experiments the basic Bessemer process was evolved by Thomas and his cousin, Gilchrist. This process consists in lining the converter with specially made bricks composed largely of lime and magnesia, and in throwing a quantity of lime into the converter before it receives the charge of iron. After the blow is given, there is a period of some minutes of after-blow after the carbon is all gone. The effect of this after-blow in the presence of the basic material is to remove the phosphorus almost entirely. In 1860 Sir William Siemen's regenerative furnace was completed.

The principle peculiarity of this invention is the way in which the heating is effected. The gas from the producer and the air for its combustion are made to pass through chambers of intensely heated fire-brick piled up loosely. Before they leave the furnace the products of combustion pass through two other such chambers. By the manipulation of valves, the course of the gas and air is changed. A sort of cumulative effect is produced by the process, and a most intense heat is developed at the expense of a comparatively small amount of fuel. Applications of the Siemens, or open hearth furnace, to making steel at once became obvious. By the Martin process a steel of any desired percentage of carbon is produced by melting pig iron and wrought iron together on the hearth. The Siemens process produces steel on the open hearth by the melting of pig iron and iron oxide. In the Siemens-Martin process both methods are combined, the product of the operation being the famous open-hearth steel. A description, or even a brief mention of the many valuable modifications and improvements that have been added to

these four great epoch-making inventions would necessitate the writing of a volume devoted exclusively to the history of the iron and steel industry.

The discovery of aluminum, the lightest metal known, is probably the most novel and notable attainment of Nineteenth Century metallurgy. The alchemists of the Middle Ages speculated on the composition of alum and decided that it must have an earthy base. About 1600 Stahl said this base was similar to lime. In 1724, Fr. Hoffman first announced the correct idea that the base of alum is a substance distinct from all earthy bases. This was demonstrated by Marggraf in 1754, and in 1760 Professor Baron, of Paris, announced that he had tried without success to reduce it to metal. Yet the belief that it would ere long be isolated was so strong that in 1762 this earthy base was named alumine. The discoveries by Lavoisier and Priestly, about 1780, led directly to the idea that alumina is the oxide of a metal that had not been isolated, and during the next forty years all imaginable methods of reducing it were tried without success. In 1824, a Swede named Oersted, discovered a method of making from alumina a combination of aluminum with chlorine, the first being an element of clay and the latter of common salt.

In 1827 Frederick Wohler, a German professor, found that metallic potassium had such a strong affinity for chlorine that it would take it from the aluminum chloride and leave the metal free. The aluminum obtained by Wohler was, however, only as a fine powder, which resisted all efforts to make it amalgamate. The trouble was to find an element with such a strong affinity for oxygen that it would take it away from the aluminum, leaving the latter free. In 1854 Ste. Clair Deville experimented with potassium with the much-desired result, but the product when obtained cost more than its weight in gold, the actual cost

of a pound of the metal being about $200. Then Deville tried the mixing of aluminum chloride with common salt, subjecting the liquid to the decomposing force of a strong electric current. The product so obtained cost but little less than the first. Then he tried metallic sodium instead of potassium, by which process he was able to manufacture aluminum at a cost of $8 per pound. No cheaper method was discovered until 1886. In that year a new process for making sodium reduced the cost of that chemical from $1 per pound to less than 25 cents. This had the effect of materially reducing the price of aluminum production, and by 1888 the metal was selling for $5 per pound, the total output being one ton weekly. But the sodium process was soon to be a thing of the past, for in 1889 Charles M. Hall, of Oberlin, Ohio, patented an electrolytic process, and started a small plant for the manufacture of aluminum on the bank of the Allegheny River, about eighteen miles above Pittsburg. The process consisted of a bath of aluminum fluoride and sodium fluoride, in which alumina has been dissolved. This mixture is kept melted by the heat of a strong electric current, which decomposes the alumina in the solution without decomposing the bath in which it is dissolved. By this process the metal is now being made at a cost less than 50 cents per pound, and numerous factories for its manufacture and that of its alloys have been established both in this country and abroad.

The possibilities of aluminum are infinite. It is about as light as oak wood, being about one-fourth as light as iron and has greater resistance than the very best steel. It stands high in the list of malleable metals and can be drawn into a wire 1-250th of an inch in thickness. It is an excellent conductor of electricity, and would at 20 cents per pound take the place of copper for all electrical purposes.

In shipbuilding, where lightness is demanded, aluminum meets every requirement. France and Germany have several aluminum torpedo-boats, and pleasure yachts are being built every year of this metal. In Germany two army corps are equipped with aluminum, the equipment including every article of metal carried on the person. Paris has several aluminum cabs, and aluminum horse-shoes and aluminum sulkies are made for some of the great racers. The Twentieth Century will no doubt see it supplant iron and steel to a great extent, as the time is certain to come when it can be manufactured as cheaply as those products. It is well known that aluminum is present in every clay bank, and it would be difficult to say more plainly how common it is. The only question is how to separate it from the clay at a cost that will put it within reach of the mechanic and the manufacturer, and as it is believed that discovery is not far off, the predicted "Aluminum Age" may be near at hand.

There is so much of the romantic and picturesque in the history of the past fifty years' developments in the mining of the precious metals and gems, that the recounting of it would seem to be more within the province of the novelist than of the sober chronicler of ordinary events. In that short period the two richest gold fields of modern times have been discovered, and diamonds and other precious stones have been found in such profusion as to cause a depreciation of at least one-third in the value of some of them, as, for instance, diamonds.

Probably the most contagious gold fever that ever spread over an adventure-loving world was that which broke out in May, 1848, when Sam Brannan, the leader of the Mormons in California, pranced through the streets of San Francisco, swinging his hat and brandishing a bottle of gold and shouting at the top of his voice, "Gold, Gold,

Gold from the American River." On the 19th of January of that year James Wilson Marshall, a carpenter, while at work on the tail race of Sutter's Mill, in Eldorado County, had made the discovery of the precious yellow metal. The outcry of Sam Brannan was as the touching of flame to tow. The whole town became ablaze with excitement. Everybody left his shop, store, or office and made a mad rush for Sutter's Mill, where the Mormon told them they would find the very river beds filled with golden gravel. The cry of Sam Brannan went all over the world, and the wonderful tale of an El Dorado was transported North, East, South, and West. It reached Hawaii first, and twenty-seven vessels, loaded with whites and natives, set sail before October 1. Two-thirds of the population of Oregon deserted hearth and home and sought the gold fields. From six cities, New York, Boston, Salem, Philadelphia, and Baltimore, sixty-one vessels, averaging fifty passengers each, set sail for California between the middle of December and the middle of January, 1849. Sixty vessels cleared for the same voyage around Cape Horn from New York alone. During the winter and spring 250 vessels sailed from Eastern ports. The long five months' trip around Cape Horn was a wearisome outlook to the feverish gold seekers. There was a mad scramble for passage on any kind of craft that would float. The California, a side-wheel steamer of 1,050 tons, was the first of these ships to pass through the Straits of Magellan. At the South American ports competition was so fierce that steerage tickets were eagerly snatched up at $1,000 each. When the ship arrived at San Francisco and the passengers had swarmed off into the jubilating town, every one of the officers and crew ran away except the captain and the assistant engineer. It was impossible to man the vessel for the return trip and she drifted helplessly

about in the bay for a long time. Before the middle of January, 1849, there was not an important shipping port in the world that did not contain at least two or three vessels that were fitting out for the Golden Gate. Even the farthest East was not beyond the stretch of the contagion. China began to throw a stream across the Pacific, and Australia placarded the streets of her chief cities with glowing signs: "Gold, gold, gold, gold in California." In the early part of the year 316 vessels from foreign ports sailed through the Golden Gate. Most of these vessels were deserted by their crews as soon as they touched the land. At one time more than 500 ships were counted in the bay, and not one could boast a crew or guard. On a par with this great migration by water was the grand overland movement that began in the spring of 1849, as soon as passage over the plains and mountains was feasible. The story of the overland route is one long tragedy. The rallying points of this migration were St. Joseph, Mo., and Independence, Mo., on the Missouri River, from which stretched the two long weary trails. Thousands and thousands of vehicles of every description rolled into these headquarters early in April. In May the great caravans set out, and before June 10, 5,095 wagons had passed a certain point on the Humboldt River trail, and it was reckoned that a thousand more were left behind on account of sickness and death, or, as often happened, massacres by the Indians. The rear ranks of the long processions of that year were overtaken by a terrible scourge of cholera, and 5,000 died on the march, while other thousands were prevented from continuing the trail.

Considering the crude processes then in vogue for the mining of gold, the yield that rewarded the brave argonauts was truly phenomenal. In the first year $10,000,000 worth was taken out; this increased to $40,000,000 in

1849; $50,000,000 in 1850; $55,000,000 in 1851; $60,-000,000 in 1852; and it reached its highest point in 1853, when a total value of $65,000,000 was recovered. During these first six years the methods of extracting the gold were very crude, and therefore very wasteful. The mining was carried on in what was termed placer deposits, and the favorite tools of the forty-niner were the pan, the rocker, the Long Tom, and the sluice box. The rich alluvial deposits becoming worked out in the course of time, the miner turned his attention to the gold-bearing rock. Then the mining of gold became a more difficult and costly matter. Science, skill, and capital were demanded, and chemistry was called in to determine the composition of the various ores. The pan, the rocker, and the Long Tom gave place to the highly organized machinery of the stamp mill, with its costly stamp batteries, amalgamating pans, and concentrating tables. In due time the rebellious ores were treated by roasting, and the various leaching processes were introduced, by which practically the last trace of gold could be recovered from the tailings. There were also perfected a number of systems of hydraulic mining, whereby enormous deposits of gold-bearing gravel can be worked to advantage. As its name indicates, the mining is done by the action of water, which is discharged under enormous pressure against the gravel bank or bowlder, thoroughly seggregating it and washing it into sluices, where the gold is deposited.

During the first flush of the gold excitement there was little or no attention paid to the mining of the less valuable metal silver, although it abounded in close proximity to the gold diggings. To the two and a half million ounces of gold taken out in 1850, there were only 38,000 ounces of silver. This rose to 12,375,360 ounces in 1870, and

reached the maximum in 1890, when it amounted to 54,517,440.

Since the discovery of gold in California, rich deposits have been located and worked in all the Rocky Mountain states and in the Black Hills of Dakota, but, with the exception of the Cripple Creek Colorado excitement of 1895-1896, nothing approaching the frenzy of '49 occurred until the news was spread that treasure of untold value had been found in Alaska. Then the scenes of the early fifties were enacted all over again. The excitement reached its height in 1898, and men, and women, too, flocked from the uttermost parts of the earth to the frozen and barren regions of the Yukon and the Klondike. The tragedies of the overland, or "backdoor route," as it is called in this case, were repeated. Bleached bones strewed the way over the Canadian Rockies and through the mountains of Eastern Alaska for thousands of miles, and the name of Chilkoot Pass became synonymous with that of death. During the winter of 1897-98 and the following summer every available vessel in the Pacific ports was put into requisition, and hundreds of thousands made the long sea journey to St. Michels, thence up the Yukon, sixteen hundred miles to Dawson City, the metropolis of the New El Dorado. Owing to climatic restraints, it has been impossible to determine the richness of the new treasure land, or to even make a conjecture regarding its possibilities.

There is not space here to even briefly describe the wonderful and costly mechanisms that have been introduced into the gold-mining industry in very recent years. The principal innovations, however, are the steam dredge, used for scraping up the gravel from rivers, and the peripatetic mining machine on wheels, built by the Pullman Company for the smelting and testing of ores.

The development of copper mining industry has been

no less remarkable than that of gold. The discovery of the famous Cliff copper mine on the shores of Lake Michigan in 1844 opened up one of the richest deposits of this mineral that has ever been known. The first recorded production was one of 12 tons, taken from this mine in 1845, which increased to 150 tons in 1848. Within the last twenty years the increase of production has been without a parallel. From 27,000 tons in 1880 it had attained to more than 200,000 tons in 1897, an amount which is greater than the total production of all the other countries of the world combined. Although copper is worth to-day only one-half what it was twenty-five years ago, the output is more than thirteen times as great. This success has been achieved entirely by the introduction of improved machinery for the mining of the raw material and in efficient processes of metallurgy in the division and refining of the ore. The great Calumet and Hecla mines in Michigan each treat not less than 1,000 tons, and often as much as 3,000 tons of rock daily. The machinery used in handling this material is the most powerful of its kind—compressors and rock drills, pumps for lifting water from the mines; huge engines for hoisting the rocks, and enormous steam stamp mills where the ore is prepared for the hydraulic processes of concentration which separate it from the copper. An immense quality of water is required by these mills—not less than thirty tons for each ton of rock treated—and in the pumping of the water from the lake some of the largest pumping engines in the world are used.

The mining and metallurgy of the baser metals—zinc, lead, and tin, and the manufacture of tin plate, have in recent years become pre-eminently American industries. The extraordinarily large deposits of zinc and lead which have been found in Kansas and Missouri have led to some

notable improvements in the methods of smelting, one of the most notable being the adoption of the electro-magnet. A new process for the manufacture of paint is one of the important outgrowths of the Kansas lead industry. The old process of manufacturing white lead by the slow corrosion of pig lead has been done away with entirely. The intent of the new process is to turn the ore directly into white lead, and to manufacture that into paint. This process started with the idea of saving white lead from the smoke and fumes of the smelter. It has reached such economical development that the ability of the workmen to stand before the furnace is the measure of the amount of lead which shall pass into the more valuable product. The heat to make the new process effective must be of the most intense character, the furnace being fed with broken car wheels or anything that will produce sufficient heat to turn the lead into smoke and fumes from which the white lead is extracted.

There have been no industrial phenomena so distinctly characteristic of the Nineteenth Century as the sudden discovery and development of the utilities of the oil and natural gas fields of Pennsylvania, West Virginia, and Ohio. The rapidity with which advantage has been taken of the newly discovered resources, and the manner with which they have been applied to the widest variety of manufacturing purposes, have resulted in important modifications in a number of industries. Although petroleum had been known from the earliest times, the history of the industry really dates from August 28, 1859, when oil was struck at a depth of 69½ feet along the banks of Oil Creek, Venango County, Pa. This well flowed a thousand gallons a day and the excitement that followed the discovery rivaled the gold stampede of ten years before. Before the close of the year 1860, 2,000 flowing wells had been sunk, and the

daily output of seventy-four of them was 1,165 barrels of 40 gallons each. Oil Creek below Titusville, the valley of the Allegheny from Franklin to Warren County, and the banks of French Creek, became one bustling city of derricks. Poor, hardworking farmers were made multi-millionaires in the course of a night. Small villages reared themselves into veritable metropolises, and a period of recklessness and wild extravagance ensued, which has never been equaled in the history of any mining camp. Although the abnormal features of the early development of this particular territory have since disappeared, it is still considered one of the richest oil-producing localities in the world. More recent but equally fruitful discoveries of oil and natural gas have been made in West Virginia and Ohio and a small district near Pittsburg, Pennsylvania, while the fields of Siberia have been opened to the world.

The development of natural gas, always to be found in greater or less quantities in petroleum territory, dates back to 1878, but it did not come into general use for domestic and manufacturing purposes until 1884. It was then piped to Pittsburg and for a few years the Smoky City lost its right to that time-honored pseudonym. In 1887 extensive gas fields were discovered in Indiana, but now, after a dozen years, they, too, have become partially exhausted, although the economy of to-day may in part atone for the extravagance of the past and make them available for a generation to come. The towns and cities that have sprung up around the natural gas centers show evidence that they may hold and increase their prosperity, even should the supply of gas become exhausted.

For many years it was thought impracticable for America to even attempt the manufacture of tin plate, and that industry, which has now reached considerable proportions, really dates its birth to the passage of the tariff act

of 1890. Since then American tin plate competes successfully with the very best Cornwall product, and in view of the fact that the Black Hills of Dakota contain 500 square miles of tin-producing district, containing more tin than all the other tin mines of the world put together, the future possibilities of the industry are unlimited. Improved methods employed in the treatment of the plates are all the results of the past forty years. With the exception of a few of the Cornwall factories, hand-made tin plate is a thing of the past. Briefly described, the present process consists, first, in placing the iron or steel sheet to be coated, in a solution of sulphuric acid or "black pickle" for the removal of the scale. Washed of the "black pickle" they are then annealed in cast-iron boxes filled with sand to exclude the air. After ten or twelve hours' roasting, the plates are passed through cold rolls and annealed a second time, when they are ready for the second, or "white pickle." After this they are dipped in the tinning pot, where they receive the necessary coating.

As has already been mentioned, the value of diamonds has in recent years depreciated fully one-third. This is due partly to improved methods of cutting and partly to the discovery of enormous quantities of the gem in South Africa in 1869 and 1870. In the beginning of the present Century diamonds were extremely scarce, because of the primitive way of working the mines, there being no machinery for the purpose of excavation. The South African diamonds were at first found in gravel surface and entailed scarcely any expense in mining. At that time the seat of the diamond-cutting industry was at Amsterdam, and the number of establishments did not exceed eight. The development of the African mines so increased the trade, however, that at present there are between fifty and sixty large diamond-cutting houses in

Amsterdam alone. Antwerp in 1870 had four establishments and 200 diamond workers; now it has eighty establishments and 4,000 workers. Large diamond-cutting establishments have also been founded in London, Paris, Geneva, and Berlin, with smaller ones in several of the minor cities of France and Germany, and it is estimated that there are now 16,500 persons engaged in the diamond industry in Europe.

Although the discoveries of precious stones in America have thus far not been such as to warrant high expectations, nevertheless gems of exceeding value have been found in various states. Sapphires of extreme beauty and great intrinsic value have been mined in Idaho; New Mexico has in late years produced some magnificent turquoises, together with opals, emeralds, and garnets. Diamonds are met with in well defined districts of California, North Carolina, Georgia, and Wisconsin. Exquisite beryls have been found in Colorado, Connecticut, Virginia, and North Carolina.

With the marvelous facilities for quarrying and shipping, the production of building stones has become one of the most thoroughly organized industries peculiar to the present Century. The value of granite produced annually in the United States approximates $10,000,000; of marble, $2,800,000; of slate, $3,000,000; of sandstone, $4,000,000; of limestone, $15,000,000, and of bluestone, $750,000.

AGRICULTURE

The origin of agriculture is lost in the darkness of remote antiquity, but not until comparatively recent times has science been applied to its practice. The ancient Egyptians, it is true, attained a proficiency in the pursuit of the art far in advance of anything seen in Europe until the end of the Seventeenth Century, if we except the work of the Saracens in Spain, who revived agriculture, as they did other arts and sciences. The Egyptian inscriptures and frescoes testify to an amazing state of enlightenment among the farmers on the banks of the Nile, thousands of years ago. Not only did Egypt produce corn enough for her teeming population, but she annually exported millions of bushels of bread stuffs. Egyptian cultivators of the soil were familiar with the value of a rotation of crops and adapted their crops to the season and soil. They were expert breeders of poultry and made a practice of artificial hatching. Their sheep and cattle were admirably cared for, being fed hay during the yearly inundation and pastured in meadows of green clover at other times. Their paintings, which illustrate rural affairs, show advanced methods of plowing, sowing and harvesting, with well-kept farms and farm buildings.

The Babylonians, the Israelites, and the ancient Romans were great agricultural nations. Later on the Romans held agriculture in contempt and fine lands, formerly highly cultivated, were allowed to go to waste. Under the barbarian conquerors of Europe, in the Middle Ages, agriculture was despised and neglected. The Saracens and their successors the Moors practiced husbandry

as an art. To this day remains of their noble works testify to their wonderful system of irrigation and to their enlightened cultivation of the soil. In the rest of Europe numerous wars and the feudal system made agricultural progress scarcely possible. The condition of the masses was such that they had neither the means nor the will to improve their holdings. All that they raised beyond the barest necessities of life was taken by those above them. Rye, barley, and oats afforded food and drink. Even the aristocracy of Europe had few edibles other than these and wheat. It is said that until the end of the reign of Henry VIII, there were no salads or edible roots raised in England and that Queen Catherine, if she wished a salad, was obliged to send to Holland or Flanders to get it.

Agriculture partook of the general improvement which resulted from the invention of printing and the revival of learning, but its progress was slow. During the Nineteenth Century more advancement has been made in the practice and science of agriculture than during the whole preceding period of history, although at the beginning of the Century the study of agriculture and the improvement of its methods had already received a considerable impetus. Jethro Tull's sensible doctrines and practices of husbandry had been made known to the world, although their merit was not fully realized; Blakewell's experiments had resulted in improved methods of breeding and caring for stock; the alternate system of husbandry had been substituted for the old wasteful and ignorant practice of sowing successive crops of corn until the land was exhausted, then turning it out to rest, in the futile belief that nature would restore its fertility; improvements had been made in some farm implements and machinery; much had been done in the way of draining land. Agricultural

societies had been founded in Great Britain and the United States.

The increase and diffusion of knowledge of agriculture during the Nineteenth Century has been remarkable. This has been accomplished through many agencies—agricultural societies, farmers' papers and magazines, lectures, agriculture colleges and schools, Government bureaus or departments of agriculture and experiment stations. As has been said, agricultural societies date from the Eighteenth Century. In the north of Italy such societies were established very early in the Century and in Scotland there was more than one short-lived association before the founding of the well-known Highland Society in 1783. In 1793 a private association called the Board of Agriculture was incorporated in England. This was supported by Parliamentary grants. It did valuable work until it was dissolved in 1816. Since then, various agricultural societies have sprung up in different parts of Great Britain and in the rest of Europe. As early as 1784 agricultural societies were established in Pennsylvania and South Carolina and in 1791 and 1792 in New York and Massachusetts. From these beginnings an almost innumerable number of agricultural societies has grown. Each state in the Union has a central organization which encourages local societies. In many states each county has its own society. A like condition of affairs exists in Canada. Much popular interest is taken in these societies. Frequent fairs are held at which are awarded prizes to fine products of dairy, farm, garden, and orchard. Horticultural and agricultural societies have done much to spread a knowledge of improved stocks, implements, and seeds.

The first agricultural school is said to have been founded by Fellenberg at Hofwyl in Switzerland in 1806.

It prospered for thirty years and over three thousand pupils were trained in it. Since then, numerous institutions have arisen in different parts of Europe, and have been conducted with success. They have exerted great influence, especially on the Continent, and it is maintained that in many countries the land now yields almost twice as much per acre as it did before the founding of these schools, colleges, and their attendant model farms. In the United States, in 1862, Congress passed a bill providing for the "endowment, support, and maintenance" of colleges of agriculture and the mechanic arts in the several states. The course of instruction covers a period of four years. The curriculum is comprehensive and includes, besides language, literature, history, and general science, botany, geology, zoölogy, entomology, horticulture, veterinary science, and the various interests associated with theoretical and applied agriculture. As a rule, the tuition is free, so that any student who is able to pay his living expenses may take advantage of the opportunities offered.

Systematical study of the farmer's problems under the Government supervision is almost entirely a development of the last fifty years. Private individuals, such as Jethro Tull and Arthur Young, long before made investigations and experiments for the benefit of humanity, but this was done at their own expense. In 1843 the experimental farms of Sir John Bennett Laws at Rothamstead and of the Rev. Mr. Smith at Lois Weedon, attracted the public attention to the benefits to be gained from methodical study. It was, however, totally impracticable for the tenant farmer of Great Britain to experiment to any extent, whatever the advantages to the world. At last Parliament realized this and in 1889 created a Board of Agriculture, whose duties in many respects resemble those of the Agricultural Department of the United States. Since

then experimental farms under the auspices of the Government and the various agricultural colleges are conducted with success. France and Germany have long carried on experiment farms. One of the best Government experiment farms in the world is in Germany, at Mockern, near Leipsic, in Saxony. It was established in 1851.

The Governmental experiment stations in the United States date from the establishment of the agricultural colleges in 1862. Each college endeavored to teach the practice of husbandry as well as the theory. Farms were bought and cultivated under the direction of the colleges. These became experiment stations. Recent legislation has systemized the work of these farms; regular reports are required from them by the Department of Agriculture and copies of such reports are sent to every other such station. There are now one or more experiment stations in each state and territory of the Union. The Department of Agriculture itself investigates and experiments in both laboratory and farm. Useful information has been collected and recorded on a multitude of subjects and all of this valuable matter is at the service of every farmer in the land. The support of the experiment stations in the Union costs the country about one million dollars a year. The commissionership of agriculture was established in 1862. In 1889 it was made a department of the Government and its chief became an officer of the Cabinet. The department embraces the weather bureau; also the bureaus of forestry, agricultural chemistry, botany, entomology, pomology, animal industry, vegetable pathology, and of experiment stations. It pays particular attention to overcoming the enemies of crops, both insects and diseases, having sent costly expeditions to foreign lands in order that they might be studied in their native haunts.

The motto of the British Royal Agricultural Society is

"Science with Practice." It is typical of the agricultural progress of the Century. Science has been applied to farming in innumerable ways. Geologists, chemists, physiologists, statisticians, architects, and mechanists have helped the farmer solve his problems. At first the tillers of the soil would have nothing to do with scientific aid, and opposed all innovations. But as capital and skill were brought to bear on farming by wealthy and enlightened cultivators of the soil, wonderful results were obtained; and, gradually, such object lessons had their effect on the masses. At the end of the Eighteenth Century, in England, millions of acres of wastes, commons and open field farms were enclosed and the present system of British farming, by which the land is owned by landlords occupied by tenants, and farmed by laborers, came into general use. Through long misuse or neglect the land had become impoverished and it was necessary to expend much ingenuity and capital on restoring its fertility. Men addressed themselves to the problem with zeal. Attention was given to the best methods of draining, manuring, and to the rotation of crops. Farm buildings were better planned and constructed, live stock was improved and better cared for.

The system of thorough drainage and deep plowing introduced by Smith, of Deanston, about 1834, is, with modifications, the one in use to-day. Good drainage has restored the prosperity of clay farms and made them sometimes more productive than the best naturally drained ones.

Agricultural chemists have made a science of manuring. At the beginning of the Century, as a rule, little attention was paid to this necessary part of farming. Half-rotted straw was the usual fertilizer, although many substances have been used to enrich soil from time immemorial. Until the present day the feeding of plants had

not been really understood and manuring had been done almost blindly. Chemistry and geology have demonstrated what is necessary to plant life and what stimulates growth. Besides water, carbonic acid, and ammonia, plants feed on certain mineral substances, such as lime, potash, magnesia, soda, sulphates, and phosphates. Certain crops exhaust the resources of the soil and these must then be restored artificially. Davy, Sprengel and Liebig led the way in the study of agricultural chemistry with valuable results. From 1835 onwards the use of nitrate of soda, guano, bones, and superphosphate spread. Manufactured guano proved almost as valuable as the natural Peruvian supply. Science has taught the farmer to use for enriching the land many things which were formerly wasted. Almost every vegetable and animal substance, in one state or another, can be used as manure, and properly applied supply the needs of plants. There is, to-day, no lack of materials and guides to the farmer who would improve and preserve the fertility of the soil. So thoroughly has the science of fertilizing been studied and set forth by competent men that the ignorance and blindness of a Century ago seem incredible.

In the United States the farmer has had a virgin soil to deal with. For years he used it wastefully, but of late he is realizing the wisdom of more careful husbandry, especially in the East, where worn out land has testified to the fact that the supplies stored in the soil by nature throughout ages can be exhausted soon by unthrifty use.

Irrigation is not a product of the Nineteenth Century, for it seems to be almost as old as agriculture itself. The irrigation-works of Egypt, Babylonia, Assyria, and China were built so long ago that no one can name the dates of their construction. Yet irrigation plays an important part in the agriculture of to-day. In India an elaborate system

of irrigation works has been built to prevent terrible famines, which cause untold suffering in arid but densely populated sections of that crowded land. In Madras alone 6,000,000 acres are watered. Great Britain has found these irrigation-works profitable investments, returning from 6 to 30 per cent per annum on the money invested and resulting in annual crop values of millions of pounds. France has blossomed like a garden with her small, well-tilled irrigated farms and her thrifty agricultural population has grown rich. In the western part of the United States hot and arid lands have been made to bear luxuriant vegetation; water has been brought from far under the earth's crust and by means of artesian well and windmill distributed over the thirsty land. The irrigation of orchards and fruit lands in California has resulted in fruit unrivaled in size and beauty, which, by means of cold storage and refrigerating processes, is sent all over the world.

During the Nineteenth Century much attention has been paid to the breeding of live stock. Great improvements have been made in all breeds of domesticated animals. Not only have individual specimens of high merit been produced, but all over the civilized world there is a much better quality to be found. Contagious diseases, such as pleuro-pneumonia and rinderpest, have been combatted successfully and by quarantine have been limited to small districts, preventing the spreading of the plague.

Agricultural fairs have done much to improve and encourage the improvement of live stock, as has the fashion of breeding pedigree animals. Among wealthy landowners in England, about the middle of the Century, there was a "pedigree mania," and fabulous prices were paid for cattle of particular breeds. This drew attention to the good points of the animals and resulted in a general dis-

tribution of offshoots from fine stock. Inspired by the success of British stock breeders, Americans imported cattle from the best herds, and the effect upon the cattle in the United States was instantaneous. In 1867 J. O. Sheldon, of Geneva, New York, sold forty head of shorthorns, known as the "Duchess," for $42,300. In 1873 a single scion of the same family brought $40,600 at public auction, and an eight months' old calf sold for $27,000. These extraordinary prices attracted the attention of farmers all over the country to the importance of the selection and breeding of cattle. As often happens, the pupil has distanced the teacher, and the average animal in the herds of the United States is to-day above that of Great Britain. The Jersey was imported in 1850. Having become acclimated and improved in strength, size, and quality, she is now one of our best dairy breeds. About 1857 the Holstein-Friesian breed was introduced. In 1896 the Department of Agriculture estimated there were 16,137,586 milch cows in the United States, valued at $363,955,545, producing 20,000,000 tons of milk.

Horses, sheep, and pigs also have been much improved during the Century. The trotting horse is a product of New England. The Puritans regarded the race course as a snare of the devil and taught their horses to trot instead of to run, little dreaming that the trotting match in years to come would be the cause of gambling like any other trial of speed on the turf. Lady Suffolk made the first trotting record below 2:30 less than fifty years ago. In the United States to-day there are thousands of horses who can trot a mile in less time, while Alix has covered the distance in 2:03 3-4. The trotting horse affected materially the art of the wagon and carriage builder in the Northern states. Carriage wagons and even agricultural machines have been constructed more and more with regard to light-

ness and beauty, and it is said that the average farm wagon of New England is prettier and lighter in draft than the carriages used by the nobility and gentry of Europe.

Spanish merino sheep were first imported to the United States in 1809. The extremely high price of wool at this period induced farmers to pay especial attention to the breeding of sheep and the production of wool. In 1812 unwashed wool sold for $2.50 a pound and merino lambs brought as much as $1,000 apiece. This was practically the beginning of the enormous sheep industry of the United States. An ingenious statistician has calculated that the 40,000,000 sheep of the United States in 1898 would, if placed head to tail in a straight line, reach twice around the globe.

The American hog is another development of the Century. The swine brought from the Old World throve and multiplied abundantly in the forests of the New World, with their plentiful mast. The Western farmer had only to turn his hogs into the woods in the early spring and herd them with their progeny; at the first approach of winter to fatten for a few weeks on corn before killing. Huge droves of them bred in this way were sent yearly through the Southern states, where the planters bought them as food for their slaves. Since clearing the forests, the enormous corn crops of the West have rendered easy the production of much finer pork, and the American hog, the result of judicious crossing of improved English breeds, is as nearly perfect as possible. In 1898, hogs to the number of 26,134,000, were slaughtered in the United States.

During the three-year drought in the states west of the Mississippi the Kansas hens saved Kansas. That the suffering in that state was far less than that in Nebraska and Iowa was due to the hens. Living on sunflower seed, a plant that required little or no water, they produced their

crop of eggs with unfailing regularity, the only crop which was unaffected by the terrible drought.

In the middle of the Century there were not more than half a dozen breeds of poultry in the United States, now there are over one hundred generally distributed through the country. Many inventions have made artificial hatching easy and profitable, and hens go on laying, while chicks are hatched and cared for by machinery. The average number of eggs laid by one hen has been increased, by original methods discovered in the United States, to from seventy-five to one hundred and seventy-five per annum. In 1898, it is estimated, the fowls of the country laid 819,732,916 dozen eggs. In 1893 the poultry of the United States was valued at $210,000,000, against $35,000,000 in 1840.

Dairy farming during the last quarter Century has grown greatly in Great Britain and her colonies, but the United States has made far more progress in the art. Germany, Denmark, and Scandinavia have long paid much attention to dairying, but conducted on a scientific basis, it is a comparatively new departure for the Anglo-Saxon. Dairy schools, literature, exhibitions, and societies and new and improved implements have all contributed to progress. In 1877 the centrifugal cream separator was invented by Lefeldt, and, since then, there have been introduced wonderful churns, butter-driers, milk-testers, refrigerators, heaters, and cheese-making apparatus. Creameries or butter factories have become common and almost all of their work is done by machinery, much of which is operated by steam. From 1840 to 1893 the value of the dairy products of the United States increased from $70,000,000 to $435,000,000. The census of 1890 reported an average of eighty-three gallons of milk per annum for each inhabitant of the United States. The

STEAM PLOW IN DAKOTA

total value of the dairy products of the world is $2,030,-000,000.

Bee culture has undergone marvelous changes during this Century of progress and invention. Adjustable hives, extractors, and comb foundations are among the aids to raisers of honey. There were over 3,000,000 colonies of bees in this country in 1896.

Agricultural machinery is almost entirely a Nineteenth Century product, and it is American invention which has made the marvelous changes which have lightened the labor of the farmer all over the world. For thousands of years there was but little improvement in agricultural implements. The tools for the cultivation of the soil at the beginning of the Century were but little better than those in use in the day of the Pharaohs. Indeed, during the Middle Ages so much that man had formerly possessed or known was forgotten or lost that it is doubtful if the period between the revival of learning and the dawn of the Nineteenth Century had brought things to a state equal to that in Egypt four thousand years ago. In the first half of the Eighteenth Century that agricultural genius, Jethro Tull, applied iron to his plows, but few were the people who followed his excellent example. His own laborers rebelled against his innovations and willfully broke his implements. Early in the Nineteenth Century the plow used most in the United States had a wooden mold board, sometimes covered with sheet iron, while the share was of wrought iron. This was succeeded by the cast iron plow, which has been gradually developed into an efficient machine made of greatly lessened weight and draft and made almost entirely of polished steel. The improved plow of to-day cuts the soil to a depth of several inches and turns it over, exposing it to the air, thus pulverizing and loosening it and fitting it for the reception of seed

and for a vigorous and healthy growth of crops. There are plows which free rich soil from stone, plows for making surface drains, mole-plows which burrow under the surface without turning a furrow and others for regulating the depth of furrows. There are also plows which cut off a thin slice of land for the purpose of killing weeds and special plows for use on hill sides. Indeed, so infinite is the variety of modern plows that it is impossible to enumerate them here.

In 1837 the Royal Agricultural Society of England offered a prize of £500 for the successful application of steam to the cultivation of the soil. No successful steam plow having appeared by 1843, the society's offer was withdrawn. In 1851 and 1852 a premium of £200 was offered, but not awarded, although a rotary cultivator, patented and submitted by John Usher, of Edinburgh, did fairly good work. The offer was renewed in 1857 and John Fowler, jr., the only maker who entered for trial, was awarded the prize. In the meantime, several other steam plows or cultivators had been patented but, when in 1858 the Royal Society again offered a prize, it was Fowler who won it. Steam plows seem to have been in general use in England before they were operated to any extent in the United States, but the first cultivation of growing crops by steam was carried on in Louisiana in 1871 on a sugar plantation belonging to Effingham Lawrence.

Axes, scythes, hoes, spades and almost every tool for manual labor on the farm has been vastly improved by American ingenuity, but a greater gain has been the substitution of beast for man in performing farm work and the frequent application of steam to agricultural machinery. In harvesting, first the sickle gave way to the cradle, and then the cradle to the reaper drawn by horses, which is,

on large farms, being in turn superceded by the steam reaper. For forty years the Royal Agricultural Society of England offered a prize for the production of a successful reaping machine, and repeatedly the advent of such a machine was heralded only to raise hopes doomed to disappointment.

In 1822 Henry Ogle, of Alnwick, England, is said to have invented the foundation of the mowing and reaping machines of to-day when he brought forth the finger-bar. His machine was received with angry prejudice by the working people, who threatened to kill its manufacturers if it was not withdrawn. In 1826 the Rev. Patrick Bell built a machine which was used for a few years and then discarded. At last, in 1831, Cyrus McCormick, of Virginia, invented a successful grain harvesting machine, containing the essential elements of every reaping machine built from that day to this. It was first successfully operated on the farm of John Steele, near Steele's Tavern, Virginia. Two years later Obed Hussey built a machine which was much like the McCormick reaper, except that it had no reel and no divider and no platform on which the cut grain could accumulate. Both of these machines were shown in 1851 at the Great Exhibition of the Industry of All Nations in London. Under the auspices of the Royal Agricultural Society of England they were tested in the field and the "Grand Council Medal" was awarded to the McCormick one, which was referred to by the judges as being worth to the people of England "the whole cost of the exposition."

Step by step the reaper was improved. Until 1849 it was used just as it was for cutting grass, as well as for harvesting grain, but in that year A. J. Purviance, of Ohio, obtained patents for inventions which made a more suitable machine for the double use. The list of inventions

which made harvesting and mowing machines the perfect automatons that they are to-day is a long one. Numerous attachments have been added and reaping machines now not only cut grain, but gather it and compress it into bundles, holding it while a mechanical binder draws twine around it, fastening it securely and discharging sheaf after sheaf.

The McCormick reaper is to-day used all over the world, harvesting grain in every civilized country, and the French Government decorated its inventor with the Legion of Honor for "having done more for the cause of agriculture than any living man."

Many interesting stories are told of the difficulties with which Mr. McCormick had to contend when he was struggling to introduce his machine. The reapers, which he made in a small blacksmith's shop on his farm, were taken by team from Rockbridge County, Virginia, across the Blue Ridge, thence by boat down the James River to Norfolk, shipped from Norfolk to New Orleans, again by river to distributing points in Ohio, Illinois and Missouri. He had not the means to manufacture the machines at his own cost, and it was not until he had traveled as an agent among the farmers of the West and obtained orders for his machines in four states that a firm in Cincinnati could be persuaded to undertake their manufacture. Mr. McCormick had still to go with his machines to his customers and, explaining their operation, prove that they would do their work satisfactorily before the buyers would pay for them. He perseveringly continued his toil as agent and instructor until his reapers had won their own way to popularity and needed no booming.

It is estimated that nearly a million harvesting and mowing machines together were used in the fields of the United States during the summer of 1898. Thousands

of these machines are exported annually, but their chief beneficiary is the American farmer. It is through their powerful aid that he has cultivated the great grain fields of the West and that he is able to compete with the cheap labor of the old world.

Less than fifty years ago the square-tooth harrow was universally used, but to-day there is an infinite variety of harrows, clod-mashers and kindred machines. In 1857 Share's harrow appeared. It was followed by the disk harrow, the smoothing harrows, spring-tooth and rotary harrows.

Among the greatest economizers of labor in agricultural machinery are the drills and sowing machines. There are different sorts for different kinds of seed, and they deposit the seed in the ground with more exactness and precision than is possible with the most careful sowing by hand, the drill being adjusted to measure spaces and quantities with unfailing regularity; whether operated by hand, horse, or steam the same result is accomplished with different degrees of speed. Manure distributers take the place of the disagreeable work with cart and shovel, avoiding all danger of unequal distribution; and there are hoes which can be operated by horse power without injury to the growing crop; turnip-thinners, which automatically thin out the rows where the plants are too thick, leaving tufts growing at the proper distances; haymakers, which enable the farmer to make hay while the sun shines faster than he dreamed of a quarter of a Century ago, scattering it so as to expose it to the sun and air, and yet others by means of which the new mown hay can be cured and dried without taking the sun into consideration or caring whether he shines or not. A successful horse-fork appeared in Pennsylvania in 1848. Since then great improvements have been made in hay forking and carry-

ing machinery, so that the farmer is saved the severe labor of pitching the hay to the back of the mow by hand. Hay can be cut, raked, cured, pitched and unloaded by machinery.

As early as 1858, at a show in England, there were exhibited over 48 threshing machines, most of which were worked by steam. Experimental threshing machines were made as long ago as the first quarter of the Eighteenth Century, but none that was practical seems to have appeared until in 1786, when Meikle, of Scotland, invented one which contained some of the essential features of those of to-day, so that with many modifications and alterations, of course, the complex modern threshing machine, comprising straw-carriers or elevators, separators and winnowing apparatus, is a direct evolution of it. The threshing machine has been carried to such a state of perfection that it is capable of performing a whole series of operations, from feeding the grain to delivering, stacked or sorted and weighed, the straw, grain and chaff. There are various modifications of the threshing machine, such as cloverhullers, cornshellers, and other seed separators. Some threshers are fixtures in barns or mills, but as a rule they are portable.

The cotton gin of to-day does not differ substantially from that invented in 1793 by Eli Whitney.

Steam has revolutionized many agricultural processes, as it has so many other departments of industry. There are now hundreds of manufacturers who turn out annually thousands of farm-engines. The farm-engine is often stationary, but there are many which can travel from farm to farm, chief among them being the itinerant threshing-machine. Steam and water and wind are all used to supply motive power for numerous operations, such as grind-

ing feed, sawing wood, shelling corn, cutting fodder, churning and pumping.

Agriculture has remained, during the Century, as in all probability it will be for many Centuries to come, the chief source of livelihood of the world's workers. Mulhall estimates that of the 201,640,000 workers in the world 98,610,000—not far from half—are employed in agriculture. It is interesting to note his figures for 1894, which show the overwhelming importance of agriculture. He estimates the number of workers engaged in various occupations to be as follows:

	Agriculture.	Manufactures.	Various.	Total.
Grt. Brit. & Ire......	2,530,000	9,030,000	5,260,000	16,820,000
France	7,220,000	4,720,000	5,350,000	17,290,000
Germany............	9,350,000	9,230,000	5,320,000	23,900,000
Austria..............	12,940,000	4,620,000	3,090,000	20,650,000
Other countries......	54,250,000	17,080,000	15,840,000	87,170,000
Total Europe....	86,290,000	44,680,000	34,860,000	165,830,000
United States........	10,740,000	5,950,000	14,920,000	31,610,000
British colonies......	1,580,000	1,170,000	1,450,000	4,200,000
Total............	98,610,000	51,800,000	51,230,000	201,640,000

There are no statistics attainable to show the increase in the value of food products during the entire Century. But Mulhall has compiled figures showing the increases since 1840, which was the beginning of the era of the improvement of agriculture. During the period from 1840 to 1894 there was an increase of 76 per cent in the production of grain in Europe and 38 per cent in that of meat, while during the same period the increase in population was 44 per cent. From 1840 to 1894 the area under crops in Europe, the United States and British colonies rose from 402,000,000 acres to 842,000,000—the number of hands being 98,000,000—which gives an average of eight and one-half acres to each. But if the economy of labor were as well understood in all countries as in the United States, where each hand cultivates

twenty-one acres, the tilled area might be two and one-half times as great as it is. Mulhall shows that the production of food, reducing all kinds to a grain denominator, is equivalent in the United States to twelve tons, and in Europe to three tons, per farming hand, which shows what an enormous waste of labor there is in Europe for want of improved agricultural machinery. European peasants undergo more severe toil than the American farmers, yet four of them produce no more food than one agricultural hand in the United States.

Mulhall gives the value of farm products of the civilized world in 1894 as follows (reckoning $5 to the pound):

	Millions of Dollars.				
	Grain.	Green crops.	Meat.	Sundries.	Total.
Great Britain & Ireland..	$ 250	$ 380	$ 275	$ 245	$ 1,150
Continent................	4,005	3,710	1,760	2,200	11,675
United States............	1,085	1,345	815	820	4,065
Britain colonies..........	155	120	95	265	635
Totals..............	$5,495	$5,555	$2,945	$3,530	$17,525

The farm products of Europe sum up a value of $12,-825,000,000, or three times as much as those of the United States, but the former occupy 86,000,000 persons, and the latter hardly 11,000,000, so that the average product per hand is three times as great in the United States as in Europe, as regards value—the average as regards food being four to one, as has been already shown.

From 1840 to 1894, the capital invested in agriculture had increased from $40,085,000,000 to $108,845,-000,000. All of these increases—and, as has been shown, in the United States especially—have been due to improved methods of agricultural production.

It is only within recent times that the world has awakened to the importance of scientific forestry. In this work the United States has been laggard, the vast tracts of tim-

ber in this country having been regarded as practically inexhaustible. Yet it is estimated that at the present rate of cutting forest land the United States cannot long meet the demand made upon it. By far the greater part of the white pine has been cut, and vast inroads have been made into the supply of other timbers. The state of New Jersey affords a painful illustration of the waste caused by wanton destruction of forests. Long ago it was "lumbered out," yet 2,750,000 acres, or sixty per cent of the whole land area, are fit for nothing but growing wood. From a commercial standpoint, as well as because of the effect of trees on climate and water-flow, men have come to see that the preservation of the forests and their replenishing is of importance. The decay of Spain, once the granary of the world, is ascribed by some authorities as due in part to the destruction of the forests, and that sections of Asia no longer "flow with milk and honey" as in biblical times, but furnish havens for hordes of bandits, is alleged to be due to the same cause.

Forests were disposed of to private individuals in wasteful fashion in Europe until about fifty years ago, when the reaction came. In France, since 1870, no sales have been made, but a policy of increasing forest land has been pursued and $40,000,000 has been spent for re-foresting dunes and devastated mountain sides. In Prussia, since 1831, trees have been planted to take the place of those cut down. Austria began the policy in 1872, and England inaugurated a reserve forestry scheme in India in 1873. In America New York has led, having first instituted a forest commission in 1885, and Maine, New Hampshire, Pennsylvania and Wisconsin have since established special commissions in charge of the enforcement of forestry laws. The President was authorized by act of March 3, 1891, to make public forest reservations, and seventeen

such, with an area of 17,500,000 acres, were established in Colorado, New Mexico, California, Arizona, Wyoming, Washington and Oregon previous to 1897. In February 22, 1897, President Cleveland proclaimed thirteen additional reserves, comprising 21,379,000 acres. Since then other reserves have been made.

Arbor Day has been established in forty-four States and Territories to encourage tree-planting, and in six States the day is celebrated as a legal holiday, and in five as holidays in schools. In this way the importance of forestry has been impressed upon the people.

In 1895 timber was being cut in Europe at the rate of 20,000,000 tons a month, and in the United States at the rate of 50,000,000 tons a month. It has been estimated that one billion dollars worth of forest products are consumed annually in the United States, representing nearly twice the value of the total output of all the mines, quarries, petroleum wells and other mineral products of the country. Three hundred thousand persons are occupied in the direct manufacture of forest and saw-mill products. Forest products have been put to many new uses during the Century. Tar, pitch, turpentine and oil of tar are more largely used in the arts. Cedar oil, sassafras oil, and wood alcohol are employed in the manufacture of paints, soaps, varnishes, perfumes, and disinfectants. Even paper and silk are made from wood nowadays, and special processes convert brushwood into a substance nutritious for feeding cattle.

A factor of importance to the farmer and a development of the latter part of the Nineteenth Century is the weather bureau, which, established, in nearly every civilized country, has resulted in saving millions of dollars worth of farm products, and also has been of great service to mariners, warning them of impending storms and

enabling them to save not only their ships, but their lives. The science of meteorology has reached such an advanced stage that it is possible for the forecaster to predict the weather thirty-six hours in advance with dependable accuracy. The popular impression as to the unreliability of the weather bureau is due to the fact that the erroneous predictions attract most attention. As a matter of fact, the forecaster is right, as statistics show, in eighty-five cases out of a hundred.

Meteorology, or the science of the weather, is a new study. Of course, rudimentary myths relating to the weather have been current since the earliest days, and farmer's almanacs are nothing new. But these means of forecasting the weather are not always reliable. The first instance of the principles of natural philosophy being brought to bear on the explanation of the complex phenomena of the weather was in the publication of Dalton's meteorological essays in 1793. Since then meteorology has become more nearly an exact science, successive discoveries having placed the weather philosophy of the untutored on a scientific basis. Beginning in 1854, meteorological reports were collected and sent out daily by Professor Joseph Henry, of the Smithsonian Institution. This was made possible by the telegraph, and with its extension the weather service in various nations began to improve. The meteorological department of the English Board of Trade was established by Admiral Fitzroy in 1857.

These services were, however, on a small scale, and were principally for the use of mariners. But with the development of the science it was thought that a wider service might be established. Through the efforts of Dr. I. A. Lapham, of Wisconsin, a resolution officially creating a weather service for the United States was passed,

and on November 4, 1870, the first weather bulletins, based on simultaneous observations, were sent out to twenty cities from Washington. The work was put in charge of the Signal Service of the War department, and Professor Cleveland Abbe originated the present system of weather forecasts. The popularity and success of the predictions and their benefit to the farmer led to the bureau being placed under the direction of the Agricultural department July 1, 1891. The success of the weather bureau under the Agricultural department has been phenomenal. In his report for 1895, the Secretary of Agriculture declares that warnings of cold waves alone secured from freezing more than $2,275,000 worth of perishable agricultural products, which otherwise would have been lost. That report has also this to say concerning the weather bureau: "The possibilities of usefulness to agriculture, manufacture and commerce are almost without limit in the increasing accuracy and capabilities of the weather bureau. The time is not probably far distant when its records, warnings and forecasts will be constantly in demand as evidence in the courts of justice and also by those purposing large investments in certain kinds of agricultural crops, in perishable fruits, in commercial ventures, and in manufacturing plants. Weather bureau forecasts in the not distant future will, no doubt, be consulted and awarded credibility just as thermometers are to-day. The usefulness of the meteorological branch of the service, wisely and economically administered, is beyond computation."

There are now one hundred and fifty fully equipped stations, located at selected points, over the United States, where observations are made by means of interesting but intricate instruments. These observations are taken at the same time each day at each point, and the result tele-

graphed to Washington and other special stations, where the predictions are made by a study of the conditions. This is possible by the scientific study which has been made of the movements of storms and the conditions by which they are governed. The forecasts and warnings are issued to the public by means of maps or bulletins, telephone, telegraph, steam whistle, flag and by the newspapers. It is a comparatively easy matter to reach people in cities or towns, but the problem is to extend the advantages of the weather bureau to those who live in small villages or remote from any post-office.

Many and varied are the uses to which the forecasts may be put. If the forecast was for rain on the morrow it would not be advisable to cut hay to-day; or, on the other hand, seeding operations might be pushed and advantage taken of the fact that rain would probably soon fall on the freshly loosened soil and thereby greatly promote germination of the seed. In winter the cold wave warnings are of immense value if the knowledge of the expected condition is rightly applied, as regards the protection of perishable products in storage, in transit, or even the delay of shipment until a more favorable time, in the care of live stock and in many other ways. If frost has been predicted the usual precautions can of course be taken as regards the protection of fruits and vegetables and sensitive plant life of all kinds, bearing in mind that a covering of straw, a cloud of smoke caused by smudge fires, or in fact any artificial covering that will tend to prevent free radiation of heat, will go a long ways toward preventing serious injury, if any, by frost.

CHEMISTRY

No story in all the "Arabian Nights," in all the transformations of mystic spell or fairy wand, is half so wonderful as the history of chemistry for the past one hundred years. We read of Cinderella's godmother and the white mice she transformed into milk-white steeds for a fairy coach scooped out of a pumpkin, but this pales into paltry insignificance by contrast with the miracles of modern science. Alchemy of old sought the transmutation of the metals. Chemistry of to-day turns stones into bread. The foolish alchemists spent centuries of unceasing toil in vain search for the elixir of life. The wise chemists take lifeless clods of earth, and from them evolve myriad things to delight the eye and to tickle the palate. We ridicule and pity alchemists in their attempts to turn mercury into gold, forgetting that our own chemists wrought infinitely greater magic when they discovered the process whereby at will they could extract from foul, filthy coal tar all the colors of the rainbow, and all the sweet perfumes of Araby the Blest. Modern chemistry, chafing under the restriction of the laboratory, has gone forth into the highways and hedges of industry, working magic all along its course. There is no art and no manufacture, however insignificant, that has not come under its beneficent influence to a greater or less extent.

With due consideration for the important and essential attainments of the period immediately preceding, the Nineteenth Century may justly claim the science of modern chemistry as its own. Of course, as far back as history goes certain chemical facts have been known and

various phenomena observed and treated of, and only by the gradual collection and explanation of such facts has the broad science of to-day been made possible. Among the nations of antiquity the Egyptians appear to have possessed greatest chemical knowledge; they smelted ores, dyed stuffs, colored glass and preserved the human body from decay. They were also familiar with medicines and pigments, soap, beer, vinegar, common salt, vitrol, enamel, tiles and earthenware. The Chinese also early became acquainted with the preparation of metallic alloys, processes for dyeing and for the making of gunpowder, niter, borax, sulphur, porcelain and paper. The Greeks and Romans derived what chemical knowledge they had from the Egyptians and the Phœnicians, but they added little or nothing to the science. Aristotle, however, advanced a theory which for Centuries exerted a great influence in the pursuit of the study. He recognized four elementary conditions of matter—fire, air, earth and water. The Arabs, when they overran Egypt in the Seventh Century, imbibed much of this knowledge, which, as a black art, they carried with them into Spain. It then became known as alchemy, the chief aim of which was to transmute the metals and the discovery of the philosopher's stone, the touch of which would convert mercury into gold, and at a later period regarded as curing all diseases. The importance of the Arabs as chemists ceased with the Twelfth Century, but their charlatanry was carried on more or less by the European alchemists until the latter part of the Seventeenth Century, when the first germs of the real science began to appear in the phlogistic theory of Stahl and the speculations of Becher.

In 1718 Geoffry brought out the first table of affinities, and in 1832 the chemical relation of heat and light were demonstrated by Boerhaave. In 1754-1759 Marggraf

added alumina and magnesia to the then known earths—lime and silica. He also extracted sugar from plants, and about the same time Macquer, of Paris, pointed out the existence of arsenic acid. Hales, in 1724, and Black of Edinburgh, in 1756, made important discoveries regarding air and aeriform bodies, showing that carbonic acid evolved during fermentation, respiration, and by the action of acids on chalk, was different from atmospheric air. About 1770 Priestley began to announce a number of important discoveries, among them oxygen, and the ammoniacal, hydrochloric, and sulphrous acid gases. Scheele contributed, in 1773-1786, chlorine, hydrofluoric, prussic, tartaric and gallic acids, also phosphoric acid from bones. During the same period, Bergman and Cavendish were experimenting with gases to the knowledge of which they materially added. Between 1770 and 1794 Lavoisier reorganized nearly all of the then known science, and the system he founded formed a skeleton which the chemists of the succeeding Century adopted. In 1787 Berthollet advanced some important doctrines in regard to affinities, and made some valuable discoveries in chlorine. Advanced organic chemistry received an impetus from the researches of Fourcroy and Vauquelin. Mineral chemistry received contributions from Klaproth, and the doctrine of combining proportions was promulgated by Richter.

Thus the entire Eighteenth Century may be said to have been occupied in organizing into the semblance of legitimate science the dismembered and scattered portions of knowledge that had been accruing from remote antiquity down through all the ages of civilization, and in rejecting and disproving many false doctrines that had so long obtained.

At the very dawn of the Nineteenth Century the horizon of chemistry widened immeasurably, and in it

shone that brilliant galaxy which included the great Berzelius, Gay-Lussac, Thenard, Brand, Dalton and Sir Humphrey Davy. In fact, during the early years of the Century chemistry was the science which more than any other engrossed men's minds. An international rivalry for priority took place between Berzelius, the Swede, Davy, the Cornishman, and Gay-Lussac, the French savant. An incalculable impetus was given the scientific movement by the establishment of various periodicals devoted especially to the publication and criticism of new discoveries. The Royal Society and the Institute of France inaugurated the custom of employing many of the great chemists of the day as lecturers. The enthusiasm that ensued was boundless.

Among the first of the notable attainments of these early years was the perfection by Dalton (1766-1844) of Richter's doctrine of combining proportions. Dalton was led to the formation of his atomic theory in 1808, by the observation that when a determined quantity of any substance unites with different quantities of another substance, the quantities of the second substance always bear a simple relation of weight to each other. The elements Dalton regarded as composed of homogeneous atoms, each different element having its own specific weight. He also discovered the law of multiple proportions, and that the atomic weight of compounds is the sum of the atomic weights of their constituents. Dalton's theories were at once admitted into the science, and formed the basis of innumerable succeeding discoveries. The expansion of gases, the relations of mixed gases, elasticity of steam and evaporation were also the subjects of Dalton's experiments, which were at a later date diffused and extended by Wollaston (1767-1829). In 1812 Brand founded the Society for the Improvement of Animal Chemistry, with

a view of extending that branch of the science known as physiological chemistry. Here was an entirely new departure.

Most intimately connected with Dalton's atomic theory was the discovery by Gay-Lussac of the law of combining volumes, in accordance with which gases unite with each other. He proved conclusively that chemical compounds are formed only in a few fixed and definite proportions. He observed that one volume of oxygen when combined with two volumes of hydrogen unites in the form of water. A large proportion of Gay Lussac's researches were in the field of organic chemistry. His investigation of the cyanogen compounds gave rise to the idea of organic radicals. The first really useful apparatus for the analysis of organic substances was invented by him. The system for determining the specific gravity of the vapors of substances, with a view of controlling their analysis, was also Gay-Lussac's idea. His applications of chemistry to the arts were of great importance, and his methods of assaying silver and gunpowder are still in use.

The debt which practical chemistry owes to Sir Humphrey Davy is incalculable. In his lectures before the Royal Society and the Institute of France, in 1816, he especially emphasized the importance of the connection between science and industry. He was the first to suggest the application of chemistry to agriculture. The most notable of Davy's researches were in electro-chemistry. At the same time that Dalton was working on his atomic theory, Davy discovered two new elements, sodium and potassium, the result of decomposing soda and potash by the electric current. By the same method he also succeeded in separating metals from the fixed alkalies, potash and soda, proving them to be metallic oxides. He disproved the doctrine of Lavoisier, so long dominant, that all acids

must contain oxygen. The idea of hydrogen acids was thus introduced, and substances which contain no acids admitted to be salts. Davy's researches upon flame and combustion were especially valuable, leading ultimately to the discovery of the safety lamp.

Thenard (1777-1857) contributed a vast amount of knowledge to the science. His division of the metals into groups, according to their peculiarities at different temperatures in the presence of water, was an important experiment. To him, also, is due the discovery of the peroxide and the persulphide of hydrogen, of boron, hydrofluoric acid and fluoride of boron.

Modern chemistry, in all its branches, probably owes a greater debt to Berzelius (1779-1848) than to any other one man. The fruit of his labors is scattered throughout the entire domain of the science. No chemist has determined by direct experiment the composition of a greater number of substances nor has anyone exerted a greater influence in extending the use of analytical chemistry. In conjunction with Hisinger he obtained the remarkable amalgam which mercury forms with what is supposed to be ammonium. He was the first to use hydrofluoric acid in the decomposing of minerals and chlorine in their analysis. One of the principle services he rendered was the development of the present theory of the science, and the introduction of an admirable system of chemical symbols, which obtained exclusively until 1832. In that year Dumas, supported by the French school of chemists, opposed the binary system of Berzelius, and substituted one which carried out Dalton's atomic theory to its logical extent. With the new system chemistry assumed a still more systematic aspect.

Like Davy, Faraday (1791-1867) devoted most of his researches to developing the relations of electricity to

chemistry. He extended the idea originally suggested by Davy regarding the identity of electricity and chemical affinity, both being but different expressions of one and the same force. His discovery of benzine and his work upon the liquefaction of chlorine and other gases and upon various compounds of carbon and chlorine, and of ammonia and metallic chlorides, have proved invaluable to the science.

The doctrine of isomerism, which was originated by Faraday, was taken up and promulgated by Mitscherlich, of Berlin (1794-1863), who discovered the laws of isomorphism and diomorphism, in accordance with which the crystalline forms of certain substances are governed.

Wohler's classic synthesis of urea in 1828, hitherto known only as an animal product, marked the beginning of advanced synthetical chemistry. A great and revolutionary epoch in the history of the science then began. The barrier between organic and inorganic bodies was at last broken down, and the domain of practical chemistry immeasurably extended. The mere catalogue of what has been done in organic synthesis would fill a volume. Immediately following Wohler's discovery, Berzelius, Liebig, Dumas, Laurant, Hofmann, Cahours, Frankland and a host of others especially devoted themselves to the doctrine of substitution, and the result was a vast number of new compounds to which further investigations are constantly adding. Since then alcohol, grape sugar, acetic acid, various essential oils, similar to those of the pear, pineapple, etc., have been formed by combining oxygen, hydrogen and carbonic acid.

The highly complex constitution of various organic products, albumen, fat, gums, resins, acids, oils, ethers, etc., is the subject of organic chemistry, the study of which has, within recent years, led to some of the most marvelous

and popular discoveries of the age. Coal tar, the waste product of the gas retort, has proved one of the great bases for synthetical work. Perkin, in 1858, patented a dye-stuff, aniline violet, and that dye marks the beginning of an enormous chemical industry—the production of the coal-tar colors.

The natural coloring materials, which previously had been the sole resource of the industry and which were found generally in their natural state in the vegetable kingdom, were in time supplanted by artificial dyes, converted from the unpromising black fluid. The first obstacle in the way of popularizing the coal-tar colors was the great expense of their production, in consequence of the small quantities in which the matter, alizarine, is found. Mitscherlich discovered that by acting upon benzine with nitric and sulphuric acids for the production of nitro-benzole he could produce a compound from which aniline might be obtained in large quantities. This change is analogeous to that of glycerine into nitro-glycerine, but the nitro-benzole is not explosive. It is an oily liquid with the delightful odor of almonds, and is used extensively in perfumery under the name of essence of mirbane.

By the action of reducing agents the oxygen of the nitro-benzole is replaced by hydrogen, and the result is aniline. The differentiation of color and the many shades and gradations of colors are due to chemical reactions caused by the presence of various acids and bases in the crude aniline oil. Aniline red, or magenta, was one of the first colors discovered, and the furor it created upon its first appearance in the world of fashion is yet vivid in the recollection of many people. The coloring matter used to produce this shade is a salt of a base known as rosaniline, which is formed from aniline oil by a process of oxidation. The oxidizing agent most commonly used is arsenic acid,

whose poisonous nature renders it somewhat unsuitable for this purpose, and there have been frequent cases of poisoning attributed to the wearing of garments dyed with this substance. Taking rosaniline as a basis, most of the other colors are prepared by the action upon it of various chemical reagents. By the action of bichromate of potash and sulphuric acid upon rosaniline aniline, violet is obtained, and aniline blue is formed by heating rosaniline and aniline oil together and treating the combined product with hydrochloric acid. The greens are formed by the addition of sulphur, and yellow by the action of nitrous acid upon an alcoholic solution of rosaniline. Aniline black is in reality a very deep green, formed by the action of oxidizing agents upon aniline oil. The bases producing these various dyes have in turn complicated reactions of their own which produce the shades and variations of colors almost to infinity. Practically about a ton and a half of coal is required to make a pound of rosaniline, but that amount possesses coloring power sufficient to dye two hundred pounds of wool.

Besides coloring matter the chemist has made, coal tar also produces carbolic acid, one of the most powerful antiseptic agents evolved by modern chemistry. Some useful dyes are also obtained from it. Its immediate source is that portion of the distillate known as the light oils, to secure which the tar oil is subjected to a treatment of caustic soda, and the mixture violently shaken. As a result the caustic soda dissolves out the carbolic acid and the undissolved oils collect on the surface, from which they can be skimmed off from the alkiline solution underneath. Neutralization of the soda in the solution takes place with the addition of sulphuric acid, and the salt thus formed sinks, while the carbolic acid rises to the surface. So powerful is this acid when refined and purified that one

part in five thousand parts of any decomposible animal or vegetable matter will for months prevent putrefaction.

Through the rapid and steady advance of synthetic chemistry in recent years the day seems not far distant when all the food now grown by nature will be prepared by chemical processes. For many years past synthetic chemistry has had an eager and jealous eye upon food making. It has progressed so far already that several great agricultural industries have been impaired by its advancement. Compounds and products that were once obtained solely by plant growth in the fields are now entirely furnished by the chemical laboratory and by direct manufacture.

The manufacture of oleomargarine is one of the most familiar examples of what synthetic chemistry has done in food making. The attempt to secure a substitute for butter was undertaken in 1869, by Mege-Mouries, at the instigation of the French Government, the purpose being to secure a cheap product that might be used by the navy and by the poorer classes. The principal points in Mege-Mouries' patent were the preparation of margarine oil by the artificial digestion of fat taken from animals, and the separation of the stearine, which melts at a high temperature by pressure. The conglomeration so produced was then churned into milk, the emulsion being facilitated by the addition of cow's udder and carbonate of sodium. The result of the process was a compound which, when salted and colored, not only bore a close resemblance to the genuine article, but had almost the same taste and general properties. Later modifications of this process have greatly simplified the making of oleomargarine, as it has come to be called. Cotton seed oil was found to be a valuable adjunct to its composition, and numerous improvements have been patented for purifying the animal fats by

fermentation and by the subsequent use of chemicals. For cooking purposes the oleomargarine has proved a substitute for butter, but as yet it is impossible for the sentimental epicure to accept it for eating purposes in place of butter, as he claims that there is absent that peculiar flavor and aroma of the milk product. Laying aside all sentimental prejudices, however, it has proved a veritable boon to the poorer classes, and so perfect has its similitude to the natural article become that stringent laws have been passed in many states of this country and in Europe, with reference to its manufacture and sale. In spite of legislation, however, the manufacture has steadily increased, and the United States alone produced 42,534,559 pounds in the year 1896-1897.

In the department of synthetic chemistry, the very recent experiments of Berthelot, of Paris, have been most marvelous. He has succeeded in so recombining the fat acids with glycerine as to produce the original fats, and he has also caused all the more common mineral and organic acids to unite with glycerine in a manner precisely analogous. In fact, Berthelot has been called the foster-father of synthetic chemistry. To clearly conceive of the impending changes which seem to be made possible by Berthelot's researches, it must be remembered that milk, eggs, flour, meat and indeed all the edibles, consist almost entirely (the percentage of other elements being very small) of carbon, hydrogen, oxygen and nitrogen. Berthelot has proved conclusively that it is possible to produce anything from eggs to beefsteak in the laboratory. The form will be different, but it will be the same identical food, chemically, digestively and nutritively speaking. To quote Professor Berthelot in regard to his revolutionary discoveries:

"One must consider the long evolution which has

characterized the development of foods and the major part which chemistry has played therein. The point is that from the earliest time we have steadily increased our reliance upon chemistry in food production, and just as steadily diminished our reliance upon nature. Primitive man ate food and vegetables raw. When he began to cook, when he first used fire, chemistry made its first intrusion upon the sphere of nature. To-day the fire in the open air has been replaced by the kitchen. Every cooking utensil now used represents some one of the chemical arts. Stoves, sauce pans and pottery are the results of chemical industries. So also modern cookery uses an infinite number of compounds—food compounds—which, like sugar, for instance, have been subjected to a more or less complex chemical treatment in their journey from the field, in which they grew, to the kitchen, in which they are used. The ultimate result is clear. Chemistry has furnished the utensils, it has prepared the foods, and now it only remains for chemistry to make the foods themselves, which, indeed, it has already begun to do."

Artificial eggs have already been produced by synthetic process, and sugars have recently been made in the laboratory. Commerce has taken up the question and a recent invention has been patented by which sugar can be manufactured on a commercial scale, by the combination of two gases, at a cost of something like one cent per pound. As the matter appears at present there is no logical reason why the synthetical manufacture of sugar should not become in time as important an industry as the making of oleomargarine.

There is also a possibility that in time coal-tar may produce sugar as well as carbolic acid and dye-stuffs. Both saccharine and dulcine (either one of which is more than 200 times as sweet as sugar) have been obtained from that

foul-looking product. The chemists have made several kinds of sugars that are not known in nature at all. Most of them are not fermentable, and for that reason are not digestible. Glucose, though not a synthetic product, is nevertheless the product of certain chemical actions. It is obtained alike from the starch of corn and potatoes, the starch being beaten to a cream and treated to sulphuric acid and marble dust. Tea and coffee are now made artificially in the laboratory, and if occasion demanded they could be produced in commercial quantities. The essential principle of both stimulants is the same. They are chemically identical in their constitution, and their essence has often been made synthetically. Chemists have succeeded in synthetically producing oil of mustard, which physicians prefer to the natural product, owing to its greater purity. They have also manufactured tartaric acid, turpentine and conine. This last is the poisonous principle of the hemlock, and is almost the same as nicotine, the essential principle of tobacco. It is thought practicable to convert it into nicotine, and when this is accomplished any sort of leaves may be impregnated with the mixture and with certain flavoring oils, and will doubtless serve as an excellent substitute for tobacco. The chemists are now able to counterfeit lactic acid, which is the sour principle of sour milk. They also make citric acid, which is the sour of the lemon. A recent achievement of considerable importance is the manufacture of salicylic acid from carbolic acid. In nature it is obtained from the wintergreen plant and from certain varieties of the willow, and it was formerly very costly. It is now made by the ton and is extremely cheap. Artificial milk is a hope of the very near future, as are also edible fats, and meats of all varieties.

The production of artificial musk from coal-tar is a wonderful triumph of synthetic chemistry. It is likely to

drive the real article out of the market before long. The perfumes of nearly all the odorous flowers, due to ethereal oils, are now produced artificially, and so perfect is the similitude to the scent of the real perfume that it is impossible to detect the difference. Attar of roses is not yet produced, but it is in sight. The thereal oil that gives the rose its peculiar odor is called "rhodonol," and the same oil is found in lemon grass and in geraniums. The ethereal oils which give to fruits their delicious flavors are all counterfeited easily, inasmuch as they are very simple chemical compounds. Already the chemists are manufacturing oil of banana, oil of raspberry, oil of pineapple, oil of pear and many others. Oil of bitter almonds has also been counterfeited, and though chemically different, it has the same flavor as the real. The methods of manufacturing brandy and liquors from alcohol and the essential oils are so familiar that they need not be commented on.

Without occupying themselves with the investigation of the transmutation of metals, chemists have ceased to ridicule the aspirations of the alchemists, although they condemn the venal spirit which actuated them. The possibility of realizing the dreams of the old philosophers has of late, however, been strongly suggested by the discovery of several remarkable examples of allotropism—a term employed to signify that the same body may exist under two or more different conditions, possessing distinct physical and chemical properties. For a long time it had been known that diamond, charcoal and graphite are, chemically speaking, identical, but the fact attracted little attention. The discovery of ozone (allotropic oxygen) by Schönbein, of Basel, and of red phosphorus by Schrötter, of Vienna, have set the chemists to thinking, and to experimenting.

In 1897 E. Moyat discovered a process of making

diamonds—very small, it is true, but nevertheless real stones, not imitations. Pulverized coal, iron chips and liquid carbonic acid were placed in a steel tube and hermetically sealed. The contents were then subjected to the action of an electric current by means of two electrodes introduced into the tube. The iron becoming liquified, was saturated by the pulverized coal, and the carbonic acid evaporated, thereby creating an enormous pressure on the iron and coal. This pressure increases the dissolution of the coal in the liquid iron. While the mixture is cooling, crystallization of the carbon takes place, partly in the form of real diamonds and partly in the form of crystals. The conglomeration is segregated by dissolving the iron in muriatic acid, and the morsels of pure diamonds are extracted.

In 1888 two French chemists, Frémy and Verneuil, produced rubies precisely similar in color and chemical composition to the natural stones, and of a size sufficiently large to be set in jewelry. It being known that the natural ruby is simply crystallized corundum, or oxide of aluminum, with a trace of coloring matter—chromium, all that remained for the Frenchmen to do was to treat ordinary alumina, containing a little bichromate of potash, with certain fluorides. The mixture was placed in a crucible that was kept constantly heated for one week at a temperature of 2,400 degrees Fahrenheit. After the completion of the process the rubies adhere to the sides of the crucible. The largest rubies thus far obtained weigh one-third of a karat. Their crystalline form, hardness and physical characteristics are in every respect identical with the natural stone.

Not content with usurping nature's duties in the production of food and gems, chemistry has also undertaken the manufacture of ice, for which a number of processes

have been devised. The permanent gases, such as hydrogen, or the compound gases, as the air, are forms of matter which, if subjected to sufficient pressure and cold, become condensed and liquid. At a temperature of 212 Fahrenheit steam condenses into water, while ammonia boils at 28½ degrees. By subjecting ammonia to pressure its boiling point is raised in proportion to the pressure. Hence, by taking ammonia gas and subjecting it to pressure sufficient to raise the temperature to a high degree, and by pouring cold water on the vessel containing the ammonia, the latter will become liquified. Removing the pressure and allowing the liquified ammonia to expand, the temperature falls very rapidly, and as much heat is lost as was added to it by compression. Numerous inventions, based upon this principle, are now in use for the commercial production of ice. The process most widely employed, however, is that of the expansion of compressed gas, or of vapor cooled under its compression.

The development of that branch of practical chemistry termed analysis, and its special application to the detection of food adulteration is probably of more importance to humanity than the triumphs of synthesis. The chemist is now able to determine definitely and exactly the ingredients of baking powders, flours, wines and liquors, spices, confections, and indeed, any article of food where there is the slightest possibility of fraudulent substitution. Were it not for the powers of analysis there would be no protection whatever against the impositions of synthesis.

In all branches of analytical chemistry constant improvement has been effected. Gas analysis was perfected by Bunsen (1863-'70). The chemist's balance has been improved by the labors of Becker. New methods of attack have been applied. By the electric furnace M. Moissan was enabled, in 1897, to isolate fluorine, which

resisted isolation for so many decades. By the utilization of the electric current rare metallic elements have been reduced from their compounds. So perfect are the processes for the analysis of the metals that the practical assayer does not consider seventy-five determinations an unusual day's work. By a chemical analysis of sea water, Professor Liverside, of Australia, in 1896, discovered that it contains from one-half to one grain of gold per ton, or from 130 to 260 tons per cubic mile, making a total of about 50,000,000,000 tons for all the oceans of the world. He also found the same sea water to contain from one to two grains of silver per ton, the gold existing as a chloride and the silver as a nitrate.

The influence of chemistry upon the industries and the arts has been incalculable. The perfection attained in the manufacture of glass, pottery, tiles and bricks presents a striking instance in chemical technology. Although glass of a more or less inferior quality had been made since time immemorial, not until in comparatively recent years has it been produced so cheaply as to come into universal use. For many hundred years it was an article of luxury only, and a heavy tax was placed upon it. Now the poorest person may use on his table, every day, glassware more beautifull than a king could buy not many years ago. Chemically glass is a silicate, or a compound of silicic acid and various bases. It is formed by fusing common sand with the carbonates of the alkalies or with the metallic oxides. Until the nature and properties of the different earths had become thoroughly understood by the chemists, glass-making was a precarious and uncertain undertaking. The product happened to be clear or dark, hard or brittle in accordance with the nature of the elements composing it. By chemical analysis glass-makers are now able to determine just what sand is best suited to the manufacture of

each variety of glass. Ordinary window glass is a silicate of lime and soda, and if silicate of potassium is added plate glass is produced. Flint glass is a silicate of potassium and lead. The effect of the lead is to give increased brilliancy, and renders it soft and easily cut. A mere trace of iron in the sand will render the glass dark. Water-glass is an alkaline silicate. It is readily soluble in water and is largely used in the arts. To obtain the great refractive power necessary for lenses and prisms, a large percentage of lead is used. Colored glasses are produced by the chemical action of various metallic oxides which have been added to the molten materials. The colors produced are found to vary with the degree of heat employed. All the colors of the spectrum may be obtained from oxide of iron; the oxides of cobalt and copper produce the various shades of blue; oxide of gold, ruby red; oxide of manganese , amethyst; a mixture of copper and iron ore, emerald green; and oxide of uranium, topaz.

The progress of the pottery and brickmaking industries has been no less phenomenal in the past hundred years. The making of china is one of the fine arts of the age, and like the manufacture of glass it has been developed entirely by the application of chemistry. The same might be said of brick-making, in which numerous improved processes have appeared. One of the most notable and recent of these is the Chambers brick machine, patented in 1887, which has a capacity of 50,000 bricks per day at a cost from the clay bank to the shed of only 77 1-4 cents per thousand.

The utilization of waste is one of the most remarkable functions of modern chemistry. It is in this that science shows her truest advance in the recognition and preservation of trifles, and in seeing them in the importance of their true relation. One of the most marvelous conquests over

waste was the conversion of coal tar to commercial purposes, as has already been mentioned. Chemistry allows practically nothing to be wasted now. Cotton seed, long the pest of the Southern plantation, is now being converted into oil, fertilizer and fuel. Sawdust and shavings, looked upon for centuries as absolutely useless, are now mixed with refuse mineral products and pressed into bricks, which are light, impervious to water and absolutely fire-proof. Formerly one-seventh of the coal mined was crumbled so fine in removing it from the mine that it was useless. This is now mixed with pitch and made into bricks that burn with an intense heat and leave no ashes. The skins and intestines of cattle are transformed into the well-known and exceedingly useful substance, gelatine, which is the same as ordinary glue, differing from it only in purity. Common glue is prepared from the trimmings of hides, and the refuse of slaughter houses and tanneries. Gelatine unites with tannin to form an insoluble compound. This reaction is the basis of the tanning process by which raw hides are converted into leather. Sludge acid, one of the most offensive wastes known to man, has been made to produce a most valuable oil. Carbonic acid gas given at breweries and distilleries during fermentation, has been an enormous waste. By a process recently patented it is all now collected and liquefied for commercial purposes. Slag, the refuse of the puddling furnace, has proved invaluable in the manufacture of paint, containing as it does 55 to 70 per cent of pure oxide. The chips of the marble cathedral on Fifth Avenue, New York, supplied 25,000,000 gallons of soda water, which is itself a concoction made possible by modern chemistry. The prominent ingredients in a glass of soda water are marble dust and sulphuric acid, neither of which is regarded as healthful or palatable when taken separately, but by the magical art of

the chemist they unite in the formation of a delicious beverage.

A good indication of the progress that is still being made in chemistry is the constant discovery of new elements. Most of these discoveries since 1860 have been made by the spectroscope, an instrument constructed by Bunsen in 1859 for chemical research, based on the use of the prism. In 1860 Bunsen discovered rubidium and cæsium; Crookes, in 1862, discovered thallium; Reich and Richter, in 1863, indium; Boisbaudran, in 1879, samarium; and in the same year Nilson, scandium, and Cleve, thulium; Welsbach, in 1885, neodymium and praseodymium; Marignac, in 1886, gadolinium; Winkler, in 1886, germanium; Ramsay and Rayleigh, in 1894, argon; Ramsay, 1888 to 1895, helium.

In 1896 a new determination of the relative weights of hydrogen and oxygen was made with more than ordinary care, and the result is that the atom of oxygen is 15.869 times heavier than the atom of hydrogen. In the same year a new element, to which the name of lucium has been given, was discovered.

In 1898 chemical science was enriched by the discovery of three, perhaps four, new elements in the atmosphere. On June 9, 1898, Ramsay and Travers discovered krypton, and a short time afterward, neon and metargon. Krypton is described as an element heavier than argon, and less volatile than oxygen or nitrogen; neon, as its Greek derivation suggests, is an entirely new and unfamiliar element; and metargon is closely allied to argon. The fourth discovery is ætherion, a new ærial gas detected by Professor Brush. Its density is only 1-10,000 of that of oxygen and it has been conjectured that it may extend indefinitely into space. Ozone has been liquefied, and the result is a fluid of indigo-blue color. This is very

remarkable, considering that liquid oxygen, of which it is but a modified form, is colorless. The density and boiling point of liquid hydrogen was determined in 1898 through the agency of a platinum resistance thermometer, and helium, one of the most stubborn of elements, was liquefied by Professor Dewar, of England, in the same year.

After a thoughtful consideration of the remarkable achievements of the present Century, it may seem to the laity that the limit of chemical research has almost been reached. But the chemist knows that his work is not done; in fact, it is but commenced. There is an infinity of problems yet to be solved by the chemists of the future.

PHYSICS

Discoveries in physics have been most far-reaching in their effects. The truths of nature's laws have been unearthed by careful experiment and knowledge of them has been responsible, more than anything else, for the achievements of the Century in industry. The physicist investigates the general phenomena of inorganic nature, and learns the properties of matter and of what they are capable. This volume is devoted chiefly to a history of the application of these principles, for all the developments of the steam-engine and electricity have been made possible by the discoveries of the physicist, while he has aided every branch of pure science. Evolution and the theory of the conservation of energy are reckoned as the two greatest physical discoveries of the Century. The importance of evolution has warranted the devoting of a special article to the subject. The theory of the conservation of energy, though accounted to be of equal importance, requires less space for its statement, and the history of its application finds a place in every chapter devoted to applied science. Like all great discoveries, it is so simple that the wonder is that it was not known thousands of years ago, yet it was a development of the Century, and only during the last two or three generations has it come to be generally accepted.

This great law owes its existence to the determination of the mechanical equivalent of heat, due to the researches of James Prescott Joule, who, at the age of nineteen, began to astonish the physicists of his day by the publication of his researches on the relation between heat and energy and

the final result of these investigations was the discovery of the law of the conservation of energy. He demonstrated experimentally in 1840 the law that the "heating effect of an electrical current is directly proportional to the square of the current flowing," but these researches reached their climax when he presented to the Royal Society his paper "on the calorific effects of magneto-electricity and on the mechanical value of heat." In this paper he showed that "an amount of energy equal to 772 foot-pounds will, if communicated to one pound of water, raise its temperature one degree Fahrenheit." Thus he showed that there is definite relation between heat and energy and that a given amount of energy can be converted into a definite quantity of heat.

Joule was only twenty-five years of age, and scientists received his discovery with incredulity. They surmised that this raw country youth was romancing, and refused to believe that his law was based on exact experiments. The knowledge of the nature of heat was slight at that period. Only a few years before heat was believed to be a form of matter termed phlogoston, whose presence was supposed to render combustion possible. Not until 1802 had Count Rumford discovered that heat consisted in motion among particles of matter and supported it by experiments, one of which was the boring of a brass cannon, the heat developed in which, in 2 1-2 hours, was sufficient to raise 26 1-2 pounds of water from the freezing to the boiling point. No loss in weight of the cannon resulting, he concluded that heat could not be matter, but was due as we know now, to motion among particles of matter. Rumford's discovery had only about secured recognition when Joule advanced his theory which was met with scorn; but Sir William Thomson verified his experiments, and J. Meyer and Von Helmholtz, of Germany, ignorant of his

youth, accepted the theories after proof, and they became the basis of the law of the conservation of energy which has placed Joule's name by the side of Newton in the scientific world.

The law of the conservation of energy teaches that the exact amount of energy which a force possesses is conserved (or preserved), even though, losing its original character, it appear in other forms. Power may be transformed into velocity, so that what is lost in the latter is gained in the former, and vice versa; or it may be transformed on the same principle into heat. No force is therefore destroyed, but only is transformed into some equivalent, capable of doing exactly the same amount of work which it, unchanged, could have done. The extent of this principle and its force and application, embracing as it does the whole phenomena of the universe, is so vast that it is possible only to give the reader a general notion of it. The practical importance of the discovery has been summarized by Sir John Herschel in these words: "First, in showing us how to avoid attempting impossibilities. Second, in securing us from important mistakes in attempting what is in itself possible, by means either inadequate or actually opposed to the end in view. Third, in enabling us to accomplish our ends in the easiest, shortest, most economical and effectual manner. Fourth, in inducing us to attempt and enabling us to accomplish, objects which but for such knowledge we should never have thought of undertaking."

We are taught then by the principle of the conservation of energy that force, like matter, is indestructible. The first thought of the reader might be that this is incredible, and he might instance the steam engine as a creation of force, while the lever and the pulley might be cited as other instances. But it is hoped that the principle will be

so explained that the reader will understand the real nature of these contrivances.

Anyone nowadays understands that the various forces of nature, such as mechanical action, heat, light, electricity, magnetism and chemical action, are so related that any one of them can be made to produce all the rest. By Joule's investigation this teaching was extended until we ascertained—as has been verified by repeated experiments—that a given amount of force of one kind would produce another kind, as that 772 units of work (foot-pounds) will raise the temperature of water from 32 to 33 Fahrenheit. In the steam-engine there is an inverse action. Here heat produces force work. Careful investigation and experiment has shown that after reckoning the amount of heat generated and subtracting that which is lost by conduction, radiation and condensation (an enormous misapplication of energy) it is always found that for every 772 foot-pounds, a unit of heat has disappeared from the cylinder. Not only has this relation between heat and energy been proved definite, but it is known that equally quantitative relations exist among all other forms of force. So we can express a definite chemical or electrical action in terms of work. We also know that quantitative relations exist between all physical forces, although the exact equivalents have not been found in some cases, such as light and vital action.

The amount of energy in the universe is constant. Some of it may lie dormant, and may be what is known as potential energy. An example of this may be had by a man drawing a cross bow. If he pulls the string back six inches and to do it requires a pull of 50 pounds, he exerts $50 x \frac{1}{2} = 25$ units of work. As long as the string is kept in the notch from which the trigger may release it, the energy is potential, just as when a ball is dropped

to the ground the energy remains potential. But when the trigger is released and an arrow is shot upwards, the experiment proves that it will rise just as many feet as is the equivalent of the original energy exerted. If the arrow weighs 1-4 pound, it will rise exactly 100 feet, making the work done by it exactly that which has been done upon it.* While it may have taken a strong man to bend the bow, it needs only the touch of a child to discharge it. So when gunpowder explodes, the real source of energy is not the man, but the separation of carbon atoms from oxygen atoms, and that has been done by the sun's rays. The energy was potential before released, but it was none the less there.

The practical value of this knowledge is enormous. Thus we know by the principle of conservation of energy that perpetual motion is impossible, and that no man can create force any more than he can create matter. And we also know exactly the amount of energy which we should obtain from the combustion of a ton of coal, and knowing this can direct our experiments to reducing the exertion of that energy in any other direction than the producing of the kind of work we require from it.

The great principle also teaches us that all the forces of nature are interdependent, and all have their origin in the sun. There is no origination on the earth. We learn that the heat of the sun is cause of all of the energy around us—winds, thunderstorms, water power, waves, rains and rivers. The inequality of the sun's heat on earth causes the winds; evaporation causes water power of all kinds—and that evaporation also produces rivers by transferring water from the ocean to the mountains. The heat of the sun supplies the power that enables plants to build up their

*It must be remembered that in this as in all physical experiments the conditions must be perfect. Thus there must be no aid or hindrance by friction, the force of the wind, etc.

tissues, and this stored energy is released by the muscular action of the animals who have fed on the plants.

To James Clerk Maxwell, who with Helmholtz had been chiefly responsible for the development of and proof of Joule's principle, the world is indebted for the kinetic or molecular theory of gases. He read a paper in 1860 at the British Association, in which he declared that gases consist of myriads of particles jostling against each other. The theory is consistent with the experimental laws of gases, and gives an insight into their behavior when subjected to various physical conditions. The molecules found by a study in gas are wonderfully minute, there being some hundreds of trillions in a cubic inch at an ordinary temperature, and these collide with each other at something like eight thousand million times a second. Experiment since has shown that any gas may be liquefied or solidified, and in fact it is now possible to draw no sharp line between the various forms of matter. All may be converted into gases, liquids or solids. They are all like ice, which, though solid, may be converted into water and then from water into its component gases.

Much progress has been made in regard to determining the nature and property of light. The corpuscular theory held at the beginning of the Century has given way to the undulatory theory, which is that light is caused by vibrations of the luminiferous ether. It is not yet explained, however, what it is that is moved. The velocity of light has been determined by the experiments of Fizeau in 1849 and Foucault in 1850—two ingenious Frenchmen who found that light travels at the rate of from 186,000 to 187,000 miles a second. It has also been found that color is due to light. With the undulatory theory of light as a basis, it has been discovered that color is to light what pitch is to sound. The agent which produces in our visual

organs the impression of color is therefore not in the objects, but in the light which falls upon them. The redness is not in the rose itself, but because the light which falls upon it contains some rays in which there are movements that occur just the number of times per second that gives us the impression we call redness. In short, the color comes not from the flower, but from the light. If the reader choose to prove this he may do so by lighting a spirit lamp, on the wick of which a piece of salt as large as a pea is placed. Then let him exclude all other light from the room, and if he brings the red rose to the light he will see that it appears to be of an ashy hue, with all the redness missing. Science declares that the fresh green tints of early summer, and the golden glow of autumn, the brilliant colors of flowers, insects and of birds, the soft blue of the cloudless sky, the rosy hues of sunset and of dawn, the chromatic splendor of gems—are all due to light and to light alone. The shades are caused by the number of vibrations. If the vibrations of ether are at the rate of 458 trillions in a second, we receive the impression we call red, if at the rate of 727 trillions, violet, and so on with the other colors of the spectrum. These discoveries have been made by the aid of spectrum analysis—a most important physical achievement, of which mention will be made in the article on astronomy.

Physicists have made many similar discoveries in regard to the properties of matter, and the work they have done is so vast, and yet of so technical a nature, that it would not only require many pages to enumerate them, but it would be tedious to the reader unacquainted with the fundamental principles of physics, while those with such knowledge can recall them with ease. In these the physicist has been aided by many delicate machines of his own contrivance, which are in themselves triumphs of scien-

tific and inventive genius. One such machine is an instrument perfected by Professor Dayton C. Miller, of Cleveland, in January, 1899, which will measure down to the twentieth-millionth part of an inch, and is used for making almost infinitesimal measurements of light waves.

Interesting applications of physical principles are to be found in the work which water and air have been made to do for us. The value of water power and of windmills was known in the remote antiquities of time, but by the compression of these two forces many things may be done which it would be difficult to accomplish otherwise. The hydraulic press, which depends on the principle that a pressure exerted on any part of the surface of a liquid is transmitted undiminished to all parts of the mass and in all directions, was invented by Braham in 1785, but many improvements have been made since. The force which may be brought to bear by means of this machine upon substances submitted to its action is limited only by the power of the material of the press to resist the strains put upon them. In the press a piston passes water-tight through a strong metal cylinder. A tube leads from the cylinder to a force pump, and thus water is driven from the tank into the cavity of the metal cylinder, so as to force the cylinder upwards. The bale of cotton, or whatever other article it may be necessary to compress, is placed on a table supported by the piston, and the rising of the tables impresses the object against an entablature supported by pillars at the top. The hydraulic press, with modifications, is used for pressing oils from seeds, where a powerful, steady and easily regulated pressure is required as well as for pressing more bulky objects. By use of hydraulic pressure cannons and steam-boilers are tested, the water being forced into them by means of a force-pump.

William Armstrong patented his hydraulic crane in 1846, and since then it has come into extensive use, it being possible to employ a pressure greatly in excess of that which may be used in the case of steam. These cranes are so arranged that one man can raise, lower or swing around the heaviest load with a readiness or apparent ease marvelous to behold. One of the simplest forms of the hydraulic crane consists of two upright cheeks between which is fixed a hydraulic ram, occupying the lower half of the upright frame. The upper end of this ram carries a pulley, and a similar pulley is affixed to the upright frame. A chain is secured to the bracket on the upright frame. This chain passes up over one pulley and down and under the other pulley, and then over the pulley on the end of the jib of the crane. The rising and falling of the ram causes the chain to ascend and descend with its load. An ingenious device by Armstrong is the accumulator, which acts as a reservoir of power, which is being always stored into that vessel. The principle of the hydraulic crane is largely used by elevators, though it is being supplanted by electricity.

Water engines are sometimes used. They are operated where water under a high pressure may be obtained, and are worked on the same principle as the steam engine.

Compressed air is a new force which is coming into general use, and is regarded by some people as likely to become a rival to electricity. At present, however, they have been rather brothers, working side by side in the industrial field; each can do many things which the other does, but each has its own field of labor. Electrical energy can be produced and converted into power with far less loss than is possible with compressed air, but much more delicate and expensive appliances are necessary, while experts must be employed for the use. On the other hand,

compressed air is a rougher workman. It can be set to work in swamps and ditches and quarries digging mud, battering rocks to pieces, and loading or unloading cars, and the men who handle it may be rough-handed, too.

Although authentic records show that as long ago as 250 B. C., Ctesibius of Alexandria applied the air as the force for an airgun, yet little progress had been made in its application until the present Century. Its first real use as power was on the drills in the famous Mount Cenis tunnel—to which allusion is made in the article in this volume on engineering. In America the first practical use to which it was put was on the Hoosac tunnel. These were the rock drills that have revolutionized the modern work of quarrying.

One of the most useful applications of compressed air is the air-brake, invented in 1869 by George Westinghouse, the use of which has reduced the danger of accident in railroad travel. The present quick-acting air-brake, known as the Westinghouse, was not constructed until 1887. Compressed air also finds its use in the railway service in the operation of switches and semaphore signals; it is used to signal the engineer, ring the bell, to sand the track, dust the cushions, clean the hangings, raise water, and it performs many other rougher duties in the railway machine shops. There are crevices which the feather-duster would not reach in cleaning cushions, but a jet of air one-tenth of an inch in diameter will reach every place and, projected with force, will carry away every particle of dust.

The principle on which these tools is operated is this: The air is compressed, and on its release it rushes forth with great force. Joule calculated in his researches on the compression of air that, assuming the whole of the energy was converted into heat, when air was compressed

under a pressure of 21.5 atmospheres, the mechanical equivalent of heat was 848.24 foot-pounds, and when the pressure was 10.5 atmospheres was 796.6 foot-pounds. The work is really done by the steam-engine or another prime mover in compressing the air. In the construction of the Mount Cenis tunnel the air was first compressed by water power and then carried through pipes into the heart of the tunnel, to work the rock-boring machines.

The same principle as that used in the rock-boring machine is employed in the little tool with which the dentist compacts the films of gold-leaf in a tooth. In these machines the part which holds the actual tool is not operated directly by the air, but just above it lies a plunger, which is vibrated back and forward by the air, and this strikes blows on the head of the working tool when the tool is pressed back against it. Tools moved in this manner are used to set up the rivets which hold together steam boilers, the iron-work of bridges and sky-scrapers, and in many shops hand-riveting has been abolished by their use.

One of the advantages possessed by tools of this type is their delicacy. An automatic facing tool used in the marble and stone-yard will prepare the surface for the hand-worker, while another takes the place of the mallet and chisel in fine work. The operator grasps a hand piece and presses the tool to the face of the stone. Air is admitted to the plunger in response to his pressure, and 20,000 blows a minute may be struck; while a man cannot swing a heavy hammer continuously more than thirty times per minute. A pneumatic breast-drill, weighing 18 pounds, with 80 pounds air-pressure, will drill a 5-16 inch hole through cast iron one inch thick in one minute. The tools are of varying size, and a great shear will cut off the end of the big steel beams that are used in ships and buildings as easily as so much tinfoil. Punches and jacks

worked in this way will do all sorts of things, from forming the top of a tin can to putting car wheels on their axles.

Compressed air operates hoists and traveling cranes in the foundries. One man in a foundry can lift heavy loads and place them on a wagon in less time than could be done by many men employing less modern methods. The advantage of its use was well shown during the excavating of the great Chicago drainage canal, when fifty air-compressors were used to excavate the channel 160 feet wide and 35 feet deep, which contained over 12,000,000 cubic yards of solid rock. Those who have witnessed the operation of these machines have an uncanny feeling as they see the great drills and hoists worked apparently without use of motive power—the noise and dust of the steam-engine being absent.

Moving air is able to pick up and carry other things with ease. An interesting application of this principle was at the World's Columbian Exposition, when the problem of painting the huge buildings seemed a Herculean task, almost impossible of accomplishment. Frank D. Millet devised a painting machine, by which the great manufactures building was kalsomined inside of a month by a double-spray machine, which covered 31,500 square feet of surface a day. The machine is like one of the atomizers that women use, but a continuous supply of compressed air is used to squirt the stream of paint. With one of these machines one man can paint thirty-two coal cars in a day or one car in fifteen minutes, and not a crack or crevice of the wood will escape the paint. The artist's air-brush is an application of the same principle on a smaller scale. When sharp sand is substituted for paint in such a machine, the result is a tool which will destroy the most stubborn of substances, and which is used to

clean steel ships of barnacles and rust, or to polish great surfaces.

It is by the aid of compressed air that the foundations of the great office buildings are sunk, and in wrecking operations it is used to force out the water from numerous barrels or bags attached by the divers, thus furnishing sufficient buoyancy to bring the vessel to the surface. It is also used for ice-making, and in compressing the bundles of kindling that are sold at the groceries. It is used in mixing in breweries, and instead of yeast by some bakers.

Compressed air has reached its greatest development abroad. It was there that the idea of pneumatic dispatch originated, it being introduced in 1853, when the force was used by Latimer Clark to transfer written dispatches through tubes between two of the stations of the Electric and International Telegraph Company. Since then its use has spread until it is used by firms and corporations for the transfer of small parcels, while nearly every post-office in an important European capital city is connected with its sub-stations by pneumatic tubes. During the past few years, such tubes have been introduced in the post-offices as a part of the postal system of Boston, New York and Philadelphia, while it is largely employed in American shops and offices for intercommunication.

In Paris compressed air is put to the most varied uses. Victor Popp, of Vienna, who exhibited his processes at the Paris Exposition, is responsible for its introduction in the French metropolis on a large scale. His first application was to what is now known far and wide as the pneumatic clocks of Paris, and of which there are now fully 10,000. He has a factory with four compressors of 2,000 horse-power each, and from this factory compressed air is conveyed around the city by means of pipes of 1.64 feet in diameter. The force is used largely to operate electric

motors. The compressed air attachment may be put into a space so small that it need not be considered, and it requires no other manipulation than the turning of a stop-cock. It is applied to printing presses and other machinery in Paris, is used to operate elevators, and for practically any purpose. The advantage of the system in force by Popp is the ease of transportation. All that is necessary is to attach a rubber pipe hose to the stop-cock of the supply, and this hose may be lengthened by the addition of other pieces of hose.

Compressed air has been used as a motive power in the mechanical traction of surface roads for nearly fifty years in France. From the mid-forties until 1859, a pneumatic way seized the train from Paris to St. Germain when it reached a steep grade, and pulled it up the mile and a half to the latter town in three minutes. As it was called into use only once during each hour of the daytime, it was finally abandoned on account of the cost. But as various methods reduced the cost of air-compression by one-half, it came into more general use. A compressed air motor has been used since 1879 to propel street railways in Nantes, and in 1894 compressed air-motors were introduced for traction purposes on the line from St. Augustin to Vincennes, at the extremity of Paris. There are three or four other lines near Paris that now use compressed air as a motive power.

In America compressed air is about to be used for the motive power of railways. Early in 1899 a plant was built for the use of the Twenty-eighth and Twenty-ninth Street lines of the Metropolitan Street Railway Company, of New York, and, if successful, the company will probably extend it. Engineers believe that the cable and trolley may be superseded by the new force. The locomotive must be charged, as is the case with the so-called storage battery

of the electrician, but a charge will propel a vehicle for from fifteen to twenty-five miles. The cost is less than a cent a mile for power sufficient to carry a weight of ten tons up a five per cent grade. So great a charge is rendered possible by the construction of air chambers of extreme strength. Early in 1899 experiments in the use of compressed air were made by the New York Central Railroad. In addition to greater speed and economy, superior advantages to the steam-engine are claimed for it in the retention of power, and in the even and regular manner in which the power is freed. With the compressed air engine a speed of sixty miles for one hour is quite as easy as a speed of twenty miles an hour for three hours.

With the end of the Nineteenth Century, and the dawn of the Twentieth, has come the discovery of a new force, more marvelous in its possibilities than either steam or electricity, although as yet it has been put to no practical use. Its development will probably be the work of the Twentieth Century, just as the Nineteenth Century has perfected and applied discoveries of the Eighteenth. Who can imagine what wondrous stories the historian of the achievements of the Twentieth Century may have to tell of liquefied air? That air might be liquefied if the temperature were made low enough has been known to chemists and scientists for years. As long ago as December and January, 1877-78 air was liquefied by Raoul Pictet, of Geneva, and by Calletet, of Paris, while on June 5, 1885, Professor James Dewar exhibited liquid air obtained at a temperature of 316 degrees below zero, Fahrenheit, before the Royal Institution, London. But the possibilities of its commercial use were not conceived until twenty years later. In March, 1897, a mysterious explosion occurred at the Endicott Hotel, in New York, which, being inquired into, developed the fact that Professor Tripler, of that

place, had been experimenting with the new force for several years, with a view to its manufacture upon a scale and at a price which would allow of its use for practical purposes. Almost simultaneously, Professor Linde, of Berlin, announced that he had succeeded in producing liquefied air at a cost which would allow of its use as a motive power for engines of different kinds.

The two methods are probably similar, although Mr. Tripler has not made public either his method of producing the air, nor its cost, as he has organized a company which he hopes will secure a monopoly of the new force. Professor Linde makes no secret of his process, and states the cost as 10 pfennigs (2 1-4 cents) for five cubic metres. Consul-General DeKay, in a report to the state department, dated Berlin, March 11, 1897, describes the machine which he uses as a most ingenious piece of mechanism, which yields the product either in fluid or gaseous form, as may be desired. Its most striking feature is its economy of working, since, once charged, the machine uses the air of the surrounding atmosphere to produce liquid air, and so goes on working indefinitely, without expense for fresh fuel. After the pump has been in operation for a certain length of time, the operator turns a cock and the liquid air runs out at a temperature of 273 degrees below zero. In Professor Linde's method an air-pump of five horse-power condenses air to a pressure of 200 atmospheres. This air passes down a spiral tube and is let out into a chamber, producing intense cold; then it rises, and, passing on the outside of the same tube through which it was conducted, bathes it and cools the fresh supply of air which has been pumped into the tube to take its place. This air, thus cooled, follows down into the chamber, and, expanding again, lowers its atmosphere, then passes up around the same spiral tube; but as its temperature has become much

lower, the new air now in the tube is still further refrigerated. This circulating process is repeated again and again, until the new air pumped into the tubes reaches a temperature of 273 degrees below zero, when it drops into the chamber as a liquid. Thus the air, steadily cooled, is made to refrigerate the newly pumped air more and more, until the necessary degree of cold for liquefaction is attained.

For transportation the liquid air can be packed in a tin can, and sent to any distance when protected by a thick layer of felt. All that seems necessary is to preserve it from the surrounding atmosphere, as is done with any other ice. There is no danger in handling it, provided it is kept away from fire and the expanding gases are allowed to escape. For this purpose Professor Tripler places felt over the mouth of the can, which keeps out the air, without confining the gases. It can be ladled out with an ordinary tin dipper; but if the dipper, while in use, is let fall, it will shatter like thin glass, the intensity of cold rendering iron and steel extremely brittle. Neither copper, aluminum, silver, gold nor platinum are so affected. Fortunately, leather is not affected either, and so can be used for valves. Rubber, however, in contact with it, becomes as fragile as porcelain. If a tumbler is filled with the liquid air, it will boil hard, and in half an hour will evaporate completely, leaving the tumbler coated with frost. But if the air is placed in a glass bulb, and the bulb set in a larger one, with half an inch vacuum between the two, so that the fluid is protected from the air outside, it vaporizes very slowly, and the tumblerful will last for several hours. In one of Professor Tripler's public experiments, he partly fills a teakettle with the liquid, and pours a few ounces of water upon it. Instantly the kettle bubbles and boils over, sending up from the spout a long jet of steam, mingled with a spray of spurting drops. The water is frozen hard almost as soon as it touches the liquid

air, and if the kettle be turned upside down, lumps of ice fall out, hard-frozen and as dry as chalk. Power enough has been generated in the process to run an engine.

The value of the liquid for refrigerating purposes can hardly be overestimated. Meat may be frozen so hard by its use that it rings like metal when struck with a hammer, and may be pounded into powder. Mercury may be frozen into a solid bar, as hard as iron, and so cold that to touch it will blister the flesh. Indeed, nothing has yet been found which will not freeze by contact with it, and Mr. Tripler predicts that it is destined to supersede frozen water for this purpose. Liquid air furnishes a clean, dry cold, which produces no dampness, and renders the transportation of meats, fruit, etc., to any distance an easy matter. In a large hotel, where the liquid air is used as the motive power for driving the dynamos and running the elevators, it might be made to serve for all kinds of refrigeration. Its discoverers claim that by its use it is quite as easy to cool a house in summer as to heat it in winter, and much less expensive, while the gas produced would purify the air, being equivalent to the purest mountain air. The temperature of an hospital ward could at any time be lowered, even in the tropics, to any desired degree, and in cases of yellow fever the "white gift of the frost" might be had at any moment. It can be handled as a motive force with perfect safety, in an ordinary engine, without requiring the intense heat which makes the duties of the engineers and stokers, on an ocean steamer, so arduous, and in submarine boats the motor itself would, in place of exhausting the air, furnish all that was needed for healthy respiration. Moreover, it is claimed that it will render the problem of ærial navigation a simple one, since all that is needed is a motor, strong, light in weight, and safe. Indeed, if one-tenth of what is claimed for the new force be true, its possibilities are revolutionary.

EVOLUTION

The establishment of the theory of evolution is generally conceded to be the scientific achievement of the age. It is the natural outcome of modern scientific research and speculation, proceeding as it does from the rapid advance of the physical sciences. Evolution has been defined as a natural history of cosmos including organic beings, expressed in physical terms as a mechanical process.

Primarily evolution is the act of enfolding or unrolling or, in the process of growth, development, as of a flower from a bud or of a bird from an egg. But the term has grown to have other and much larger meanings. It is applied to a system which undertakes to explain the existence of all things inorganic and organic, physical and psychical, including the arts and institutions.

Dim foreshadowings of a theory of evolution were put forth by the early Greek philosophers. Anaximander, Empedocles and Anaxagoras are credited with having caught faint glimmerings of the truth, and it has been maintained that Aristotle, the father of natural history, held opinions as to the causes of diversity in organic beings not unlike those entertained by the geologists of to-day. However this may be, in the long ages between the days of these speculative Greeks and modern times, there was no development of the theory anticipated by them.

In the Eighteenth Century Linnæus and Buffon formed conceptions of a progressive organic development, but did little to throw light on the idea. Immanuel Kant, in 1755, published a theory of the mechanical origin of the universe, which was a true nebular cosmogony. Dr.

Erasmus Darwin, the grandfather of Charles Darwin, about 1794, put forth remarkable suggestions pointing to evolution, and the poet Goethe evidently believed evolution to have occurred in the organic world. LaPlace, in 1796, published his "Exposition du Systeme du Monde," in which in a footnote appears his celebrated "nebular hypothesis." But his explanation of his views as to the evolution of the stellar universe and solar and planetary systems belongs to the Nineteenth Century. Thus it was not until this Century that a definite statement of the theory of Evolution appeared. In 1809, Lamarck published his "Philosophie Zoölogique," and in 1815 his "Histoire Naturelle des Animaux sans Vetèbres." In these he framed a distinct hypothesis of the progressive development of animals and plants, setting it forth with an elaborate exposition. Like conclusions were drawn by Geoffrey Saint-Hillaire in his work "Sur le principe de l'unite de composition organique," which appeared in 1828. But the theory of evolution gained few converts. Between the "Philosophie Zoölogique" and the "Origin of the Species" only one volume was devoted entirely to evolution. This was the "Vestiges of the Natural History of Creation," which was published anonymously in England in 1844. Yet in the interval botanists, embryologists and geologists were approaching the theory which astronomy had done so much to prepare men's minds to receive.

The authorship of "Vestiges" is attributed to Robert Chambers. Adopting the Nebular Hypothesis, he passes in review the development of stars and solar systems, presenting a scholarly and skillful exposition of a whole philosophy of cosmic evolution. After outlining the geological history of the earth, he treats of the origin of life from inorganic matter and the development of the animal kingdom through many stages to man, adopting the Aristotelian

idea of an internal impulse or tendency towards progression. With much care he shows the reasonableness of his view, arguing that it agrees much better with the known facts of nature in every department of her work than does the idea of a special creation of each distinct species of plant and animal. The book made a great sensation, not unlike that which greeted "The Origin of the Species," fifteen years later. Four editions were issued in the first seven months, and, in nine years, ten editions were exhausted. By 1860 about 24,000 copies were sold.

Early in the Eighteenth Century Linnæus had announced the result of his study of the stamens and pistils of plants, and by his sexual system opened a new era in the history of botany. He divided plants into sexual and asexual, the former being Phanerogamous or flowering, and the latter Cryptogamous or flowerless. But Linnæus paid little attention to the functions of plants, and did not advance the study of the embryogenic process. His followers busied themselves with classifying and describing. These branches of botany made great strides and, during the early years of the present Century, the "natural system" gradually displaced the "artificial system" of Linnæus. The opening up of America, Australia, South Africa and New Zealand to naturalists gave them vast treasures to classify and arrange, and so fully occupied their attention, that it is little to be wondered at that the physiological study of plants was comparatively neglected. In 1815 Trevirnanus called the attention of botanists to the embryo, and in 1823 Amici discovered the existence of pollen tubes. Brogniart and Brown followed in their footsteps, Brown tracing the tubes as far as the nucleus of the ovule. These discoveries laid the foundation of the present science of the embriology of plants.

Robert Brown, Sir William Hooker, John Lindley, and

George Bentham are among those who did so much to establish the natural system of classification. In 1830 appeared Lindley's "Introduction to the Natural System of Botany." Sir William Hooker was the author of several works dealing with cryptogamic plants. This investigation was of peculiar importance, for among the various mosses, ferns and other plants described collectively as "cryptogamic" were numerous types showing intermediate structures bridging over gulfs of difference in organization which might well be thought impassable. Such discoveries were of much value in paving the way for biological evolution.

The man who did more than any other geologist to further the doctrine of evolution was Charles Lyell. In the first part of the Century it was maintained that the earth had undergone a series of catastrophes and revolutions, through the agency of which mountain and vale strata and rock had been formed. As late as 1830 Cuvier's "Essay on the Theory of the Earth" was the accepted authority on geology, and it was generally believed that, as he taught, mountain peaks and ridges "are indications of the violent manner in which they have been elevated." "It is in vain," announced this apostle of the catastrophists, "we search among the powers which now act at the surface of the earth for causes sufficient to produce the revolutions and catastrophes, the traces of which are exhibited in its crust." Thus it was believed that the "revolutions and catastrophes" had been extremely violent, perhaps fatal to all organic life on the globe, and followed by new exercise of creative force. In 1830 appeared the first volume of Lyell's "Principles of Geology," a work which undermined the very foundation of the catastrophe theory. Clearly and convincingly the author showed that the position of Cuvier and his followers was wholly untenable

when viewed in the light of the facts of nature. The most ancient formations of the earth were proved to have been formed, ages ago, in the same way and by means of the same physical agencies that are at work to-day.

The views of evolutionists were placed on a scientific basis by the patient labors of biologists, who applied themselves to the question of the mutability or immutability of species and the extent of variation, as shown by observation. There was a sort of scientific dogma to the effect that species were immutable and, as no tenable account of transmutation was put forward, naturalists refused to relinquish it.

In 1858, two essays were read before the Linnæan Society, one by Charles Darwin, entitled, "On the Tendency of Species to Form Varieties, and on the Perpetuation of Species and Varieties by Means of Natural Selection," and the other by Alfred Russell Wallace, entitled, "On the Tendency of Varieties to Depart from the Original Type." Although these two papers setting forth the same discovery were given to the world at the same time, to Darwin belonged the prior claim. Through years he had been perfecting his theory of Natural Selection. A voyage around the world on the "Beagle," with Captain Fitz-Roy's expedition (1831-1836) gave him remarkable opportunities for pursuing his investigations in natural history, the love for natural history being in his case innate.

He says: "During the voyage of the 'Beagle' I had been deeply impressed by discovering in the Pampean formation great fossil animals covered with armor like that on the existing armadillos; secondly, by the manner in which closely allied animals replace one another in proceeding southwards over the continent; and, thirdly, by the South American character of most of the productions of

the Galapagos Archipelago, and more especially by the manner in which they differ slightly on each island of the group, none of the islands appearing to be very ancient in a geological sense. It was evident that such facts as these, as well as many others, could only be explained on the supposition that species gradually became modified; and the subject haunted me. But it was equally evident that 'none of the evolutionary theories then current in the world' could account for the innumerable cases in which organisms of every kind are beautifully adapted to their habits of life. . . . I had always been much struck by such adaptations, and until these could be explained, it seemed to me almost useless to endeavor to prove by indirect evidence that species have been modified."

This was the starting point. Soon after his return from the voyage Darwin opened, as he says, "his first note-book for facts in relation to the origin of the species, about which I had long reflected, and never ceased working for the next twenty years." By "printed inquiries, by conversations with skillful breeders and gardeners, and by extensive reading," he collected facts, seeming to know intuitively what was necessary to the solving of the problem. Stock breeders were more or less consciously, by selection, improving the domesticated animals and forming new races. Nature must by "selection" form new species, but how did such selection become possible?

"In October, 1838, that is, fifteen months after I had begun my systematic inquiry," says Darwin, "I happened to read for amusement 'Malthus on Population,' and, being well prepared to appreciate the struggle for existence which everywhere goes on, from long continued observations of the habits of plants and animals, it at once struck me that under these circumstances favorable varieties would tend to be preserved and unfavorable ones

destroyed. The result of this would be the formation of new species."

Although he now had the clue to the whole subject, not until 1842 did he allow himself to sketch his theory. In the meantime he accumulated pertinent facts with patience and industry, working on the true Baconian principle. In 1842 he made a brief sketch of his theory, elaborating it two years later into an essay of 230 pages. He showed this sketch to Lyell, Hooker and others, but still did not make known to the world his discoveries and conclusions. A letter to his wife, written at this time, charges her, in case he should die, to devote £400 to publishing the essay. But it was long before Darwin, living, was ready to publish it. From 1846 to 1854 he busied himself with preparing an extensive monograph on recent and fossil cirripedes, but in 1856 he began to write out on a large scale a work dealing with the origin of the species. He was interrupted by the arrival of a paper from Alfred Russel Wallace who, far away in the Malay Archipelago, had solved independently the problem to which his friend Darwin was devoting so much attention.

In 1855 there had appeared an article by Wallace, "On the Law Which Has Regulated the Introduction of New Species." He had deduced the law or generalization that "Every species has come into existence coincident both in Space and Time with a pre-existing closely allied Species," and showed that much was explained by this hypothesis, and that no important facts contradicted it. Three years later, while ill with intermittent fever, he fell to considering the problem of the origin of species. He had read "Malthus on Population" about ten years before, and, recollecting what this author said about the "positive checks" war, disease, accident, famine, etc., which have the effect of keeping savage populations nearly stationary,

it flashed upon him that kindred checks must act upon animals, since they increase so rapidly that otherwise their numbers soon would be immense, instead of there being but little variation from year to year. Vaguely pondering on the matter in the intervals of the fever, then came, as if by inspiration, the idea of the survival of the fittest—that it must be the weak that perish, while the strongest and best survive. As soon as he was able, Wallace sketched out this theory and sent it by the next post to Darwin.

But for the persuasions of his friends, Hooker and Lyell, Darwin would have generously published Wallace's freshly completed manuscripts, holding back his own, the fruit of so many years of patient investigation and thought. But, yielding to solicitation, "in the interests of science," he accompanied Wallace's essay with one of his own, and the joint communication was read before the society. Thus was the theory of the survival of the fittest, or of Natural Selection, given to the world.

Before this there had been anticipations of the theory, but they had attracted little attention, and do not seem to have come to the notice of either Wallace or Darwin. The latter, in after years, made a collection of these expressions of thought, giving full credit where credit was due. In 1813 Dr. W. C. Wells read a paper before the London Royal Society, entitled "An Account of a White Female, Part of Whose Skin Resembles That of a Negro." In this he recognizes the principle of Natural Selection as applied to the races of men. In 1831 Patrick Matthew published a work called "Naval Timber and Arboriculture." In the appendix was a brief statement of a theory of the origin of the species, of which Darwin says: "The difference of Mr. Matthew's views from mine are not of much importance," and, "He clearly saw the full force of

the principle of Natural Selection." Not contented with this generous acknowledgment of his work, Matthew is said to have gotten out an edition of his book bearing on the title page, after his name, "Discoverer of the Principle of Natural Selection." As Darwin whimsically says, he may be excused for not discovering a theory of Natural Selection in a work on naval timber. In 1822 the Reverend William Herbert, afterwards dean of Westminster, advanced the opinion that "botanical species are only a higher and more permanent class of varieties," and that the same fact is true of animals. Others who expressed views pointing to Natural Selection are Leopold von Buch in 1825, Professor Grant, of Edinburgh, in 1825, Karl Ernst von Baer, in 1828, J. d'Omalius d'Halloy, of Brussels, in 1846, Isidore Geoffroy Saint-Hillaire, in 1850, Franz Unger, in 1852, and Charles Naudin and Herbert Spencer, also in 1852.

On November 24, 1859, Darwin's "Origin of the Species" appeared—"an epoch-making book," it is justly called. Its full title is "The Origin of Species by Means of Natural Selection; or the Preservation of Favoured Races in the Struggle for Life." It was received by an outburst of antagonism, and controversy, both scientific and popular, at once began. A month before its publication, Darwin had written to Hooker, "I remember thinking, above a year ago, that if I ever lived to see Lyell, yourself, and Huxley come around, partly by my book and partly by their own reflections, I should feel that the subject is safe, and all the world might rail, but that ultimately the theory of Natural Selection (though, no doubt, imperfect in its present condition, and embracing many errors) would prevail."

Lyell, Hooker and Huxley all "came round." Said Huxley, voicing the sentiment of scientists like himself:

"That which we were looking for and could not find till Darwin and Wallace published their views, was a hypothesis respecting the origin of known organic forms, which involved the operation of no causes but such as could be proved actually at work. . . . . The 'Origin' provided us with the working hypothesis we sought." So simple was the solution, the key to the "long sought hypothesis," that after mastering it, Huxley exclaimed: "How extremely stupid not to have thought of that before." Huxley's acceptance and advocacy of Darwin's theory did much to influence the public and advance popular opinion. That Darwin appreciated Huxley's indorsement of his work is shown by what he said after his adoption of the theory. "Like a good Catholic who has received extreme unction, I can now sing 'nunc Dimittis.'"

Seven years before the appearance of the "Origin of Species," Herbert Spencer published a skillful and logical essay contrasting the creation and development theories, removing from evolution much of its former vagueness. In 1855, three years before Darwin's and Wallace's essays were read before the Linnæan Society, appeared his "Principles of Psychology," which is based on the theory of evolution. Darwin, Wallace, Spencer, Huxley and Tyndall are called the five great apostles of evolution. Their services to the establishment of the theory were performed in essentially different ways, although Wallace's work, in many respects, resembled that of Darwin. Darwin was an indefatigable collector of facts, with an infinite capacity for taking pains. Little by little he collected data from which might be deduced logically and connectedly the laws and generalizations which he sought. We have seen this in the patience and unwearying labor with which through years he verified his conclusions in biological evolution. Not content with confining himself to the col-

lection of facts testifying to the truth of biological evolution, Wallace was a self-constituted champion of evolution as a whole, valiantly defending it against the attacks of conservatism, making use of his acquaintance with geological phenomena, appreciating the confirmatory evidence found in every field of exploration, and anticipating the new psychology.

Spencer brought to the battle-ground a true philosophical mind and a fund of information justly characterized by John Stuart Mill as "encyclopædic." Gifted with a remarkable power of analysis, a vivid grasp of far-reaching principles, and independence of opinion, Spencer constructed a philosophy of evolution built on a solid basis and covering all things both concrete and abstract.

Huxley was not so broad-minded as his co-laborers, being dogmatic and singularly lacking in spiritual imagination. But he lived up to his creed of "veracity of thought," and never hesitated to avow unpopular conclusions if convinced of their truth.

Tyndall was the orator and physicist of evolution. An Irishman, he was born with intense imagination, a fiery zeal and an eloquent tongue. When Darwin announced his discovery of the cardinal truth of organic evolution, Tyndall championed the cause with all his eloquence and zeal at a time when his support was of especial value, for his brother physicists were standing aloof, as though the question of evolution were no wider in its scope than that of the famous one over which its battle was first fought —the origin of species. With his scientific knowledge Tyndall combined the ability to speak and write plainly to the general public. He was the interpreter of the laws of light and heat and other physical and chemical phenomena, revealing their mysteries to the non-scientific world. His imagination emphasized the spiritual side of

his nature and led him to place a value on the unseen which was not felt by Huxley.

We have seen how the term evolution, as used to-day, has two significations, one the widely philosophical, embracing the whole cosmical process, and the other, that of the biologist, expressing the development of organic life. Herbert Spencer, to whom we owe the modern use of the word evolution, insists on a distinction, applying "evolution" to the all-embracing philosophy and "development" to biological processes. Besides his use of "evolution" we are indebted to Spencer for the happy phrase "survival of the fittest," which Darwin adopted and sometimes used as an alternative for his own expression, "Natural Selection."

It will be well to review briefly what the theory and practice of evolution have revealed in various sciences.

In astronomy, the oldest of the sciences, instead of the fixed systems of bygone ages, evolution presents the beautiful nebular hypothesis with its suns and worlds beginning, continuing, disintegrating in the infinitude of space exactly as they have been doing through æons of time. The astronomer watches these vast phenomena and knows he beholds embryonic, existing or dying stars or planets all conforming to physical laws which govern equally stars and atoms. The meteoric hypothesis, which has been revived by Lockyer of late years, substitutes diffused solid meteoric matter at first without heat for the gaseous nebulæ of Laplace's hypothesis, and assumes that the heavenly bodies have been formed from the condensations of meteoric clouds; but from a mechanical point of view, if this were true, the evolution of the universe would have taken place very much as though the beginning were gaseous nebulæ.

Geology takes our planet and shows how, through

millions of years, through gradual and natural agencies, sea and land, mountain and valley, strata and rocks, gravel and clay have been formed; how fire and water and ice performed their part in this wonderful world making; and how kindred processes are going on all around us. She proves that life has existed on the earth for untold ages, exhibiting relics of organic beings buried in rocky layers several miles in thickness. In the lowest strata traces of only the lowest types of life are found. Gradually the fossils of higher forms appear. Fishes follow invertebrates, amphibious animals come after fishes, reptiles succeed mammals and last of all appears man.

Biology studies these fossil forms and finds that the law of growth is from low to high and from simple to complex in accordance with the general principle of evolution.

When classified by the taxonomist all the plant and animal life of the globe resembles a great genealogical tree branching out into infinite ramifications, and it is no insignificant confirmation of the theory of evolution to observe how some fresh light is thrown upon each ramification that has been developed, by each new fossil which is discovered. It is interesting to note that from 1831 to 1881 the number of animals known and described increased from 70,000 to 320,000. At the time of Linnæus' death only 11,800 species of plants were known; now the number cannot fall short of 100,000.

The study of function has familiarized the student with the phenomena of sex and embryology, of heredity and environment showing the countless modifications undergone and "the continuous adjustment of internal relations to external relations." It was not until after Darwin's theory of the origin of species and of natural selection had been accepted in its extreme conclusion by Huxley, Spen-

cer, Lyell, Lubbock, Rolle, Haeckel, Canestrini, Francesco, and others that Darwin published "The Descent of Man in Relation to sex." In America Asa Gray was one of the first to support Darwin's theory.

Gathering data from every available source, studying the adult as well as the infant mind, the mind diseased and the mind in perfect health, the psychology of to-day, tentative and speculative though it may be, shows that its phenomena are governed by the same laws as the concrete world. The psychologists find the same difficulty in bridging over the gulf between the psychic and the physical life and functions that biologists have in deriving the organic from the inorganic. But Herbert Spencer has demonstrated that the preliminary sciences of physics and biology furnish many suggestions for the study of psychology.

Anthropology shows man developing from a rude and untutored savage, covered with fur, with canine teeth, and bestial habits, living on raw meat and uncooked roots which he dug from the earth with his hands, hiding from his enemies in a cave or roosting in a hollow tree, with no language save inarticulate cries of rage, pain or passion, a creature compared to whom the bushman of South Africa or Digger Indian of the West is a civilized human being. It shows the gradual growth of customs, institutions, arts and sciences, and the history of races, nations and individuals all conforming to the laws of evolution.

And so in every science has evolution lent its aid, for while many authorities refuse to accept it in all its details, it is none the less used universally as a working basis.

GEOLOGY

The Nineteenth Century has witnessed the nativity of geology. The momentous event was heralded in 1815 by the publication of William Smith's "Map of the Strata of England and Wales." This remarkable document has justly earned for its author, a simple land surveyor, the appellation of "the father of geology." It was the result of more than twenty years' mighty effort on the part of a man sadly handicapped by the necessity of earning his bread in the meantime. Apart from his pure, unselfish love of knowledge, the chief incentive that led William Smith to undertake this herculean task was his previous discovery of the two primary laws which were to form the nucleus of the new science. The first is the law of stratification, which recognizes that the rocks exposed on the earth's surface are portions of layers, and that these layers must rest successively on each other in the order of their antiquity. The second is that each stratum may be identified by its contained organic remains, which include both animal and plant fossils.

While the humble surveyor was pursuing his pilgrimage among the rocky fastnesses of England and Wales, a bitter controversy was being carried on between the two schools of geologists then recognized in Europe—the Neptunists and the Vulcanists. The Neptunists were the followers of Karl Werner, the eminent German professor of Freiberg. The Vulcanists owed allegiance to Dr. James Hutton, who died in 1797. The Neptunists advocated the production of rocks by aqueous deposition alone; Werner's theory being that "The earth had been originally

covered with an ocean, in which the materials of the minerals were dissolved." In the course of time, through pressure, chemical precipitate and crystallization, the mountains emerged from this "chaotic fluid," and "on the retirement of the ocean, certain universal formations spread all over the globe, and assumed at the surface various irregular forms as they consolidated." The Vulcanists, on the contrary, refused to indulge in any such cosmological speculations, but insisted rather that Nature is her own interpreter. To account for the metamorphoses of which the earth's crust bore record, they cited the action of volcanoes and earthquakes, and of rivers and ocean, and appealed to all the processes of decay and renovation now at work. When the Geological Society of London was established in 1807, with the object of encouraging the collection of data and of recording observations, irrespective of theory, the foundations of the Huttonian school were materially strengthened, and with few exceptions all the great geologists down to the present day have been adherents of its doctrines.

The Vulcanists accounted for the origin of the earth in this way: That the elementary parts of creation were diffused in the universe in the form of gas or vapor; the gases, having an affinity for each other, were attracted around a common central point, thereby forming an extensive gas globe, which later became ignited; through the emission of heat, this igneous conglomeration gradually cooled off on its surface, which in time became hard and condensed. As the hot mass in the interior seethed and boiled, the crust was broken through from time to time, and empty spaces and great fissures were formed on the surface of the earth. The excrescences so formed were the primitive rocks, and are considered as the first stage in the formation of the earth's surface. The next stage is

the period during which the water exercised its influence. The gases, still hanging about the earth in a thick, heavy mist, became gradually condensed as the cooling of the earth continued, and formed a great ocean that submerged the entire globe. The waters were boiling hot, and contained elements whose chemical action affected a part of the formation of the surface. Various deposits were made, and through the activity of the raging waters mountain chains formed themselves, and corresponding elevations and depressions took place. The cooling of the earth continued until the temperature sank so low that vegetation could form itself upon the earth. The climate was intensely hot, and spread itself equally over the entire surface, from the poles to the equator. First plants and then animals of an incredible size came forth luxuriantly and in the fullness of life. Then a frightful revolution took place. The shape of the earth surface was changed, and the splendid fauna and flora gradually diminished in proportions, and many of the species became totally extinct. At last the temperature sank so low that ice formed itself in various localities of the once tropical earth, which now emits no more heat than it absorbs from the sun.

The inception of the Geological Society may be said to have marked the beginning of the transition period between the epoch of hypothesis and the era of strict philosophical induction in which the geologists of the present day are trained. The society included in its membership some of the most brilliant men of the period, such as MacCulloch, Murchison, Lyell, Buckland, De la Beche, Fitton, Greenough, Conybeare, Francis Horner, Scrope, Warburton, Sedgwick, Wallaston, Whewell, and Mantell. Unlike William Smith, they were most of them in possession of independent fortunes and unfettered by the cares of the world. The laws of stratification, as set forth in William

Smith's map, became the chief subjects of study for the English geologists, who had heretofore paid little or no attention either to fossils or to the succession of rocks. In 1825, when a royal charter was granted the society, it had two well defined objects in view. One was to extend William Smith's method of arrangement of the secondary formations of England, Ireland, and Scotland. These rocks underlie the carboniferous system, and owing to their inaccessibility, they had been left by the geologist for future classification. The other task was to deal a death blow to what was known as catastrophic geology, which assumed that the globe had been the scene of a long series of catastrophies, alternating with epochs of comparative repose. The combatants of this theory were termed the Uniformitarians, and their leader was Charles Lyell, a young barrister who joined the society in 1819, shortly after taking his degree at Oxford. The young scientific recruit brought with him all the enthusiasm of genius and the exalted aspirations of youth. He was fired with the ambition to prove the gradual passage from past geological ages to the present one, and in order to do this it was necessary to travel beyond the narrow confines of Great Britain. Accordingly, he started out on a five years' sojourn, traveling through France, Germany, Italy, Switzerland, Spain, and Sicily, and studying all the volcanoes, glaciers, large rivers, and lofty mountains which those countries respectively contain. In January, 1830, the first volume of his "Principles of Geology," appeared, and the name of Charles Lyell was emblazoned on the scroll of the Immortals. In May, 1833, the second volume appeared, and created no less sensation than the earlier portion of the work. The catastrophist doctrine died a lingering death,

and the infant science became forever purged of all crude speculation.

It would be invidious to attempt the enumeration of those who contributed to the early knowledge of the science, and it would be impossible in a work of this kind to go into the details of their wonderful discoveries. In 1831 Adam Sedgwick, professor of geology at Cambridge, attacked the geology of North Wales, a task which entailed three years of hard labor. In the meantime Roderick Impey Murchison, the close friend of Sedgwick, was hard at work in Central Wales, the results being finally embodied in his classic masterpiece, "The Silurian System," which appeared in 1838. From 1836 to 1839 the two friends worked in conjunction on the transition rocks of Devon and Cornwall, which resulted in the establishment of the Devonian system. At this juncture occurs one of the saddest incidents in the history of the science. A dispute arose between the two comrades over the question of nomenclature—a dispute which led to a life-long estrangement. Sedgwick insisted that a certain series of rocks should bear his name, while Murchison contended that they should be designated the Lower Silurian, as they properly belonged to that system. Researches in later years confirmed Sedgwick's contention, and the matter was compromised by conferring the name Ordovician on the stratum that had been the cause of so much bitterness.

In the meantime geological research was traveling apace in the United States. The American Philosophical Society of Philadelphia had begun the publication of geological papers very early in the Century, and on January 10, 1809, William Maclure read at one of its meetings his memorable essay, entitled "Observations on the Geology of the United States, Explanatory of a Geological Map." The author had undertaken a gigantic task—one

infinitely greater than was occupying William Smith in England. Alone and at his own expense he made a geological survey of the entire United States, a work which earned for him the name he has received of the "father of American geology." The work was one of many years' duration. He crossed the Allegheny Mountains fifty times, and visited almost every state and territory in the Union. He traced the great groups of strata then designated as the transition, secondary and alluvial, from the Gulf of Mexico to the St. Lawrence. After an exhaustive exploration of our own country he went to Europe in order to recognize the corresponding formations of the other Continent, and in 1816 and 1817 he studied the formations of the Antilles.

About this time the importance of geological surveys, with the view of ascertaining the agricultural and mineral resources of large and unexplored regions, was beginning to be appreciated by the United States Government. The first geological survey made by state authority was that of North Carolina in 1824 and 1825, and the example was soon followed by more or less thorough surveys of the New England and Middle States, and later of the greater Mississippi valley and the Rockies. In 1841, shortly after the appearance of another great work, entitled "Elements of Geology," Lyell visited America, where he was received with great acclaim. Thirteen months were spent in the United States, Canada and Nova Scotia, during which time he worked hard as an observer and recorder. The science had meanwhile grown to gigantic proportions since he had issued the final installment of his "Principles," in 1833. The subordinate branches of geology were being studied with enthusiasm, and the importance of paleontology for chronological purposes had become recognized. It was now possible for the geologist to trace the

IDEAL LANDSCAPE—(CHALK PERIOD)

1 Megalosaurus, 2 Iguanodon, 3 Hylaesaurus, 4 Laclaps Aquilunguis, 5 Mososaurus Hoffmanni
6 Elasmosaurus platvurus

changes which the earth's crust had undergone, and to describe in minute detail the character of the plant and animal life peculiar to each of the great epochs into which time had been divided.

The solving of the mystery of the coal formation was attended by the most marvelous revelations. The fossiliferous strata of the subcarboniferous age, bore mute testimony that the greater part of North America, Europe, and Great Britain had been submerged to a considerable depth under the sea, immediately preceding the coal-bearing period. Then there were gentle oscillations, and in time the Continents had uplifted themselves to the water's surface, and in this condition they had remained for a very great period of time. The interior of the North American Continent from Eastern Pennsylvania to Central Kansas was one vast jungle of luxuriant vegetation. The Green Mountains separated the New England and Nova Scotia areas from the marshes of Pennsylvania, and the Michigan coal area was an isolated marsh region. The plants and trees that flourished in these great marshes during the progress of the carboniferous age were of a luxuriance that has never been approached in any later period. The fossil remains found in coal beds indicate that palms, phenogams, or flowering trees, and conifers, or plants of the pine-tribe, attained a colossal size. It is impossible for the imagination to conceive of the gorgeousness that then clothed Mother Earth. There must have been great numbers of immense floating islands, carrying groves, in the inland seas that the marsh regions enclosed, and the warm humid atmosphere was no doubt heavy with the perfumes of myriad flowers of gigantic proportions.

When the plants and trees died their remains fell to the ground of the forest, and soon became decomposed into

a black pasty mass, to which was added year by year the continual accumulation of fresh carbonaceous matter. Thus this process of decay and disintegration went on among the shed leaves and trees until a bed of uniform thickness would be formed over a wide area. The eras of verdure during which these plant beds were in progress were alternated by periods of inundation by salt water from the oceans, that destroyed all terrestrial life. The accumulations of thousands and thousands of years of vegetable growth and decay became covered up with deposits of sediment. Then the continental surface, or wide portions of it, would again slowly emerge and a new era of verdure appear. Thus the alternations continued until all the successive coal beds were formed. The ever-increasing pressure of the accumulated strata above them compressed the sheddings of a whole forest into a thickness in some cases of a few inches of coal, and the action of the internal heat of the earth caused them to part, to a varying degree, with some of their component gases. The coniferous trees, such as the living larches, pines, firs, etc., gave rise for the most part to the mineral oils, their sheddings having been subjected to a slow and continuous distillation, the oil so distilled accumulating in troughs in the strata, or finding its way to the surface in the shape of mineral oil springs. The nature and property of the coal to be formed depended upon the original substances of the living plant. One of the most remarkable things in connection with coal is the state of purity in which it is found. Owing to the fact that the forests must have abounded with streams and rivers, it is surprising that so little sediment found its way into the coal-beds. This puzzled the geologists until Sir Charles Lyell explained it. He noticed on one of his visits to America that the Mississippi River is highly charged with sediment where it

flows through the cypress swamps, but that when it passes through the close undergrowth the sediment becomes precipitated, and the water filters through in an almost pure state. This accounts for the presence of thin "partings" of sandstone and shale which frequently occur in coal deposits.

The seas of the carboniferous age abounded in animal life, as is evidenced by the organic remains found in the alternating strata. Fishes and sharks of mammoth size inhabited the warm waters of the deep oceans and crinoids and corals, an infinite variety of articulates, crustaceans, and trilobites infested the more shallow salt water areas. The forest jungles teemed with insect life—spiders, scorpions, centipedes, may-flies, cockroaches, and crickets. There were also numerous varieties of land snails. In this age reptiles make their appearance for the first time. Their footprints as impressed on the carbonaceous beds of Pennsylvania indicate that they were large animals and that they had tails, tail marks being discernible on the mud flats over which the reptiles marched. In the Nova Scotia coal measures fossils have been found of the sea-saurian, a species of reptile that had paddles like a whale. Before the last period of the carboniferous age had passed away, there were still higher reptiles—those that lived on the land, but so far there is no indication that birds or mammals existed as early as this period. To account for the stupendous movements which must have happened in order to bring about the successive growths of forests one above the other, the geologist attributes them to the action of heat and to volcanic convulsions. At the close of the deposition of the carboniferous system of strata, there was unusual volcanic activity, as is evidenced by the frequent occurrence of what is known as faults.

A glance at any modern geological map shows the

bountiful manner in which nature has laid out beds of coal upon the ancient surfaces of our earth, America alone containing no less than 196,660 square miles of coal-bearing territory.

More important even than the determination of the coal-making processes, was the promulgation of the Glacial theory. In 1835 De Charpentier, a Swiss geologist, advanced the idea that the erratics and bowlder clays of his country had been deposited by glaciers at some remote period. This led all the geologists of Europe and America to investigate a question that had been puzzling scientists for a long time. In America and Europe, over the Northern latitudes, stones, gravel, and sand, as well as masses of rocks hundreds of tons in weight, are found as far as a hundred miles, and more south of the region where they were originally formed. The transported material was called drift, and the stones and bowlders were formerly claimed as proofs of the tumultous action of an universal deluge. In 1840 Agassiz, of Neuchâtel, in company with J. D. Forbes, noted as an expert in the physics of glacier ice, and W. Buckland, began a systematic study of the Alpine glaciers. Their gigantic task led to startling results. It seemed an impossibility for science to accept as a fact that nearly all of Europe and North America had been enveloped in a great ice sheet many miles in thickness, and in a comparatively recent period. That ages of tropical splendor should have been succeeded by such frightful desolation was beyond all conception, but as the investigation proceeded the fact was proved beyond the shadow of a doubt. A study of the topography of North America revealed the fact that an immense glacial deposit had embraced the whole Continent from Labrador and New Foundland to the western borders of Iowa, and even farther west, and that it extended southward to the parallel

of 40 degrees. In Europe it extended down to 50 degrees, where the temperature corresponds to that of the parallel of 40 degrees in North America. The stupendous ice fields did not remain stationary, but in time began to transport themselves either in a southward, southeastward or southwestward direction. The highest mountains were no obstacle to their progress, and they moved over the great summits of the White Mountains and the Green Mountains as if they had been so many mole hills, and left as souvenirs of their visit bowlders picked up 200 miles north. The direction of transportation was determined by tracing the rocks and bowlders to those parts of the Continent where they were derived. Masses of native copper have been found in Indiana and Illinois that were transported from the Lake Superior region. From the Connecticut valley bowlders of red sandstone were carried to Long Island, and giant masses of rock have been found in the Mississippi valley 1,000 miles away from their native stratum. As reasoned by Agassiz, moving ice is the only known agent adequate for transportation on so vast a scale. The reason given for the uniformity of the direction of moving is the immutable law that a glacier moves in the direction of the slope of its upper surface. The snows being more abundant to the north during the glacial era, and the temperature being lower than at the south, the accumulation naturally became greater in the north; as a result, the movement would be southward. South America had its corresponding glacial era, transportation taking place in the direction of the equator. The cold of the era is attributed to the elevation and extension of Arctic lands and a corresponding increase in Arctic land-ice.

In 1862 Prof. A. Ramsay aroused a great controversy among geologists regarding this glacial theory. He

claimed a new and novel effect for glaciers, and set forth his opinion in a paper read before the London Geological Society. The basins of the Alpine and various British lakes he attributed to the erosive action of ice, while his opponents held that the effect of ice is abrasive, not erosive. Although Ramsay's theory won many supporters among his contemporaries, it is generally rejected by the best geologists to-day.

The logical confirmation of the glacial theory added one more period to the history of the earth, which modern geology has now divided into four grand epochs—Archæan time, Paleozoic time, Mesozoic time, and Cenozoic time. These epochs are divided into periods, with reference to the character of the fossil evidence of former organic life contained in their respective strata. Paleozoic time, which was probably three times longer than all later time, contains three ages: The Silurian, or Age of Invertebrates; the Devonian, or Age of Fishes, and the Carboniferous. Mesozoic time consists of but one age, the age of Reptiles. Cenozoic time is divided into two ages, the Tertiary, or Age of Mammals, and the Quaternary, or Age of Man. This classification represents more than fifty years' indefatigable labor on the part of the paleontologists of Europe and America. The impetus which the publication of Lyell's "Principles" gave to the study of fossils has never abated, and every available region in England, France, Germany, and the United States has been thoroughly explored. An enumeration of those who have contributed to this gigantic undertaking would be but a mere catalogue of names.

In America the progress of discovery and research has been unparalleled, until it has become par excellence, an American subject. In 1859 Joseph Leidy discovered the bones of a prehistoric quadruped in the basin of an ancient

Rocky-Mountain lake. A vigorous exploration of all the older lake basins of Wyoming, Utah, New Mexico, and Dakota revealed the fact that the western part of North America had once been the home of mammoths, rhinoceroses, tapirs, horses, and other quadruped animals. The two men who have probably done more than any others to develop American paleontology are Professor Marsh, of Yale College, and the late Professor E. D. Cope, of Philadelphia, vertebrate paleontologist of the United States Geological Survey, both men of immense fortune. From 1876 to 1885, Professor Cope had from three to five expeditions always in the field, the expenses of which he bore himself. When the fossil beds of Kansas, Colorado, Dakota, and Wyoming, the greatest known, were discovered, Professor Cope and Professor Marsh assumed the mighty task of excavating, shipping, and classifying these remains of the Reptilian and Mammalian ages. Thirty-seven species of serpents were found in Kansas alone, varying from ten to eighty feet in length, and representing six orders. Some of them were terrestrial in habit, many were flyers, and the others inhabited the salt ocean. The extent of the sea westward was vast and geology has not laid down its boundary, but it has been conjectured to be a shore now submerged beneath the waters of the North Pacific ocean. Out on the expanse of this ancient sea huge, snake-like forms rose above the surface, and stood erect, with tapering neck and narrow shaped head, or swayed about describing a circle of twenty feet radius above the water. This extraordinary neck was attached to a body of elephantine proportions, the limbs were two pair of paddles, and a long serpent-like tail balanced the body behind. The total length of the Elasmosaurus Platyurus, Cope, for such it has been named, was fifty feet. In many places as many as eleven of these leviathan

monsters would be discovered curled up together among the rocks. It was indeed an Age of Reptiles. Flying Saurians filled the air, and flesh-eating lizards, from twenty-four to thirty-five feet long, crawled over the earth, bearing burdensome tons of flesh on two bird-like feet. A flying saurian of the Mesozoic period, discovered by Marsh, spread eighteen feet between the tips of its wings, while the Pterodactyl Umbrosus, Cope, covered nearly twenty-five feet with its expanse.

The most important discovery made by Cope was the skeleton of the Phenacodus Primævus, considered the ancestor of all hoofed animals. In life it was four and a half feet long, not quite so large as a yearling calf, and when it skipped along it fluttered a pair of wings. This strange animal belonged to the first period of the Tertiary Age, during which time the American Continent began to assume its present outlines. Only the borders of the Atlantic, the Gulf of Mexico, and the Pacific were covered by the sea. The Rocky Mountain region was above the sea. The Ohio and Mississippi were independent streams emptying into the gulf, and the Great Lakes began to assume their present form. Great forests extended from one end of the Continent to the other, and giant sloths, mastodons, elephants, rhinoceroses, and camels roamed the length and breadth of the land. Immediately after this age of abnormal life came the glacial period, which was in turn followed by the Age of Man.

The progress of the science of geology in the United States was greatly accelerated by the establishment of the office of Director of Geological Survey on March 3, 1879; the department being placed under the direction of the Secretary of the Interior. The survey was organized in four branches, geological, topographical, publication, and administrative, and within each of these branches are sev-

eral divisions. Since its establishment, nearly fifty thousand square miles have been surveyed topographically, the survey being of special service during the past few years in the development of mineral resources, as well as contributing a vast amount of knowledge to the science in general.

ASTRONOMY

Progress in astronomy has been so great during the Nineteenth Century that a mere catalogue of the discoveries, and those to whom they are due, would fill vastly more than the space that we have at our disposal, and the work of the astronomer being such that scores of men aid in the making of various discoveries there would be endless controversies as to whom the credit should be awarded. Hence, in this chapter we shall give merely a few of the more important discoveries typical of the direction in which the star-gazers have been working and tell of some things that have been learned about the solar and sidereal heavens during the Century.

Astronomy was further advanced than any other science at the beginning of the Century and during the period there have been no discoveries of great principles rivaling Newton's researches in gravitation. It was known long before the beginning of the Century that the world is not the all-important center of the universe, that it is only one of several planets revolving around the sun, and that that sun was itself only one of millions of other similar suns that we call stars, and each of which probably has planets revolving around it, some of them larger and others smaller than the earth. Man had come to a realization that his earth was to the universe less than a grain of sand was to the earth. We know of the existence of hundreds of millions of stars like our sun and the nearest star of these is more than 200,000 times as far away as our distance from the sun. These last facts, learned within the last hundred years, illustrate the tendency of astro-

nomical research during the Century. The knowledge of the laws governing heavenly bodies having been discovered, the astronomer of the Nineteenth Century has directed his efforts to finding out what the stars are, and their nature. Their chemistry and physics have been investigated by aid of the spectroscope and the large telescopes have enormously increased the number of stars visible while the application of photography to astronomy has rendered telescopes even more powerful in detecting the presence of celestial bodies and recording their motions.

This attention to detail has been necessary because of the vastness of the subject. Before the days of great telescopes the naked eye of a few astronomers covered the heavens after a fashion. But the new telescopes magnify so greatly that if every man in the world were an astronomer with his eyes glued to a different telescope, and each looked at a different part of the heavens, their whole range would not be covered. And so the astronomer of to-day regards star-gazing as a small part of his duties. There are scores of men who spend a good deal of time at the telescope, but for these there are hundreds of astronomers who never look into a telescope at all except for amusement. The post of observer is not the most important at an observatory, and one active observer will keep ten men busy doing difficult sums in mathematics that lead to their conclusions. Hence the astronomer is familiar with but few stars aside from those he makes his specialty. He knows half a dozen or so and if he wishes to know anything about the others he can find their location in the star catalogue; yet not one astronomer in a hundred has observed one thousandth of the stars that are known to exist.

The discovery of the planet Neptune, which is accounted the greatest astronomical discovery of the Cen-

tury, affords an excellent illustration of astronomical methods. Five planets, or stars revolving around our sun with fixed orbits, Jupiter, Saturn, Mercury, Venus, and Mars had been known to observers of the heavens from the earlier ages, but no addition had been made until William Herschel, then organist at the Octagon Chapel at Bath, had, with the aid of a home-made telescope, discovered on March 13, 1781, the orb which received the name of Uranus. It had been overlooked by earlier astronomers, who had mistaken it for a fixed star. After the discovery of the new planet astronomers looked over the investigations of ancient observers, and, knowing that it would take Uranus eighty-one years to travel around the sun, and the direction of its path they were able to figure where it should have been at various periods in the history of the universe. It was also found that Uranus was not traveling in the course that it should have taken. By 1845 it was the "intolerable quantity of two minutes of arc" out of the way. The only way in such a deflection could be accounted for was by the supposition that it was due to the attraction of gravitation from some planet other than those whose effects had already been made known. From this it followed that there must be another great planet in the solar system besides those of which astronomers then knew.

The search for the new planet might be made by telescope, but that would be like hunting for a needle in a haystack. So two young astronomers set themselves to the effort to figure its location by the aid of mathematics. Only two had the patience and thought it worth while to pursue the calculations. They were Leverrier, of France, and Adams, of England. After each had spent about two years in independent mathematical calculations, both succeeded in finding the track of a hypothetical planet, as well

as circumstances of its motion, which would account for the irregularities in Uranus' orbit. At about the same time they announced where the planet was to be found and the locations agreed within a half of a degree. All that was necessary was for astronomers to point their telescopes to the spot indicated. This they did on the night of September 23, 1846, and Neptune was added to the list of planets in the solar system.

The discovery of Leverrier and Adams is chiefly interesting as a proof of the correctness of theoretical astronomy. Sooner or later Neptune would have been discovered by the means of the star charts that are made. Such observations, together with greater telescopes, have brought about the discovery of the asteroids or small planets. All of these discoveries were made during the Nineteenth Century. Piazzi, the Sicilian astronomer, found the first member of the group on the very first night of the present Century. Pallas was discovered by Olbers during the next year, Harding found Juno in 1804, and the fourth, Vesta, the only one brilliant enough ever to be seen with the naked eye, was observed in 1807. Encke discovered the fifth asteriod, Astraea, in 1845; three more were discovered in 1847 and since then every year has added to the list, until at the close of 1898 there were 429, six having been added during the year 1898. The new discoveries have been made possible by the use of photography.

Thus the knowledge of the existence of asteroids, and hence their study, has been a development of the Century. Of those we know, Medusa, 198,000,000 miles from the sun, is the nearest to that body, and Thule, which is 400,000,000 miles distant, is the furthest away. Professor Barnard at Lick Observatory measured the diameters of Ceres, Pallas, and Vesta, micrometrically, and found that

Ceres is the largest, with a diameter of 488 miles. Pallas is 304 miles in diameter and Vesta 248 miles, while with the exception of Juno, none of the others are greater than 100 miles in diameter, while some are not more than 10 or 12 miles. These Asteroids are located in the space between Mars and Jupiter, and, being in a bunch, the general belief is that they are a part of single planet which either failed to unite in accordance with the nebular hypothesis, or else that they are fragments of an exploded planet.

The first calculated return of a comet was that of Encke's, on May 24, 1822, which was another triumph of theoretical astronomy. Discovered by M. Pons, November 26, 1818, its orbit, motions and perturbations were determined by Encke, who declared that it should return every three years and fifteen weeks, and it has done so in accordance with the calculation. We now know of the existence of 680 comets, although there must be vastly more—perhaps hundreds of thousands—for, although it is seldom that one is not in sight, yet many too small for our telescopes to detect must be near us all the time. Much has been learned about the nature of comets and astronomers declare nowadays that so far from threatening the earth with danger they do not exert the slightest influence. The most imposing feature of the comet is its tail, and this has been found to be seldom less than 5,000,000 miles in length, in the case of those visible to the naked eye, while several are known to have been 100,000,000 miles in length, a length 120 times as great as the diameter of the sun—which latter body is 109 times the diameter of the earth. Cometary matter is so rare that Babinet in 1857 announced that a comet's tail traversed by the earth might be unnoticed. It is certainly so diaphanous that even the stars may be seen through the visible portions of a comet. Babinet also estimated that the chance of a collision be-

tween the head of a comet and the earth is so slight that it can occur only on an average of not more than once in about 15,000,000 years. The close connection of comets with the periodical showers of meteors, usually observed in August and November, was first demonstrated by H. A. Newton, of Yale, in 1864, and is now universally admitted. Astronomers suppose the meteors to be the result of the gradual disintegration of the comets. When the earth was passing the track of Biela's comet (discovered by Biela, an Austrian, in 1826) on November 27, 1872, she encountered a wonderful meteoric shower, and it was then declared that Biela's comet was shedding over us the pulverized products of its disintegration.

Comte, the French philosopher and mathematician, who was perhaps the wisest man of his day, declared that it was impossible for us ever to know anything as to the materials of which the stars were composed, because they were so far from us. The distance is great, it is true. Light traveling from the sun at the rate of 186,000 miles a second requires 499 seconds — or about 8 1-3 minutes — to reach us, while light coming from the nearest star traveling at the same rate of speed requires seven years to reach us, and from the most distant known from 2,000 to 3,000 years. Thus the problem of learning anything about the materials of which the stars are composed might well have seemed impossible even to a man like Comte. But the problem has been solved and we are now able to tell of what certain stars are composed—or at least if we cannot tell all the ingredients of which they are composed, we can tell a great many of them. We have, for example, the same certainty of existence of iron in the sun as we have of its existence in the poker and tongs on the hearth.

A remarkable train of discoveries leading to the con-

struction of the spectroscope is responsible for the revelation of the nature of the substances that enter into the composition of the heavenly bodies. That process is called spectrum analysis. Two centuries ago Sir Isaac Newton made his celebrated analysis of light by means of a prism. Every one who is at all observant must have noticed that if a strong light, especially sunlight, falls upon the triangular prisms used to ornament gas fixtures, spots of light containing all the colors of the rainbow will be cast upon nearby objects. Students of science investigated to learn the cause of this action. It was soon ascertained that the shape of the prism and its position to the direction of light would change materially the size of the spot. The reasons for this have been fully investigated, and the stock of knowledge relating to the subject is very extensive, but we will not go into it any further than is necessary for the purpose of this article. If a properly constructed prism is fixed in a darkened room so that a small ray of sunlight, coming from through a hole in the door, strikes it at the proper angle, a band of colored light, called a solar spectrum, will be thrown upon a screen placed at a suitable distance. The color of light at one end of this band will be red and at the other violet, while the intermediate colors will be orange, yellow, green, blue, and indigo. The band of light is like a slice cut from a rainbow. Close inspection with a suitable magnifying glass by Wollaston in 1802, revealed the existence, however, of quite a number of dark bands of different widths and located at different distances from each other. Fraunhofer was the first person to study these lines, and he gave a detailed description of them in 1814. Instead of looking through the prism with a naked eye he used a telescope, placing the prism and the telescope a distance of twenty-four feet from the slit, the virtual image of which was thus con-

STELLAR PHOTOGRAPHY

Photograph of Half Moon, Paris Observatory

Photograph of the Milky Way, Lick Observatory

siderably magnified. Fraunhofer gave a detailed description of these lines and showed the exact position of the more prominent ones, which are therefore known by his name. These lines are always seen in the same position when the light that passes through the prism is that of the sun, but if a candle or a gas-jet is used such will not be the case. Some of the light and lines will disappear and other lines, that were not in position before, will come into view.

Experiments carried on by others since Fraunhofer developed the fact that if in the flame of a gas-jet different substances be burned, the lines shown in the spectrum cast by the prism will be changed, and that certain materials will produce certain lines, while others will produce entirely different ones. It has also been found that the actual number of dark lines in the sun spectrum is vastly greater than was at first supposed. As many as 3,000 have been counted with properly constructed instruments. Inasmuch as different substances burned in the flame develop different lines in the spectrum, it was at once inferred that an instrument so constructed as to properly note their number and position would afford ready means for determining the composition of combustible substances. Kirchoff and Bunsen devised such an instrument in 1859, and it is known as the spectroscope. There are many types of this instrument, but the essential parts are one or more prisms, a slit through which the light examined is allowed to enter; a tube having at the other end a lens to render parallel the rays from the slit; a telescope through which the spectrum is viewed, and usually some apparatus by which the different lines may be identified. It is so arranged that two spectrums can be compared—one that of a substance whose spectrum is familiar, and the other that of the substance whose spectrum is to be examined.

At first spectrum analysis was used to compare the spectrums of various earthly substances to detect the presence of this or that element and it afforded an absolute detection of any adulteration, while by its aid, as has been told in the article on Chemistry, many new elements of great rarity have been discovered. One of these that affords a striking instance of our knowledge of the composition of celestial bodies is helium. During an eclipse in 1868 Professor Lockyer discovered the presence of a substance in the sun, and being at that time unknown on earth, it was named the sun element—helium. For twenty-five years we knew it only as an element in heavenly bodies, but in 1895 Professor Ramsay obtained a gas from a rare mineral named Clevite, which is found in Norway, and the spectrum of this gas proved it identical with that of the helium of the stars.

Numerous experiments have shown us just what materials must be burned to produce many of the dark lines in the solar spectrum, and in this way we have ascertained that the gaseous covering contains, among other things, iron, magnesium, calcium, chromium copper, zinc, nickel barium, sodium, and other elements, in all thirty-six, known on the earth. Knowing the composition of the surface of the sun we gain an idea of that of the interior mass. The stratum of gases outside of the sun is known as the chromosphere, and is brilliantly scarlet, because of the predominating presence of hydrogen gas. Like a sea of flame it covers the photosphere or shining surface of the sun to a depth of 5,000 to 10,000 miles, and though intensely hot, there is no real burning such as combustion as we know it.

By spectroscopic and other examinations of the sun and its rays, it has been found that the sun's light is a mass of heated carbon and we receive 600,000 times as much

light from the sun as from the full moon. The sun is surrounded by an extensive and rare atmosphere, the photosphere, the invisible source of solar light; the chromosphere, chiefly of hydrogen gas, and the corona, a vast shell of unknown vapor many thousands of miles in thickness. The diameter of the sun has been found to be 852,000 miles, or 109 times that of the earth, and, as it is a perfect sphere, its surface is 11,900 times as great as that of the earth, while its volume exceeds the earth 1,305,-725 times, and its mass is 332,260 times that of the earth. Its density is about one-quarter that of the earth, or rather more than that of water. The heat received from the sun is thirty calories, from which it is computed that the amount of heat reaching this world from the sun in a year would be sufficient to melt a shell of ice 165 feet thick all over the earth's surface. Lord Kelvin calculated that the quantity of fuel required for each square yard of the solar surface would be no less than 13,500 tons of coal an hour—equivalent to the work of a steam-engine of 63,000 horse power. The temperature of the sun is estimated at from 16,000 to 18,000 degrees Fahrenheit. The earth receives only about one part in each 2,200,000,000th part of the total radiation of heat from the sun. The distance of the sun from the earth (by Copernicus) was supposed to be 4,800,000 miles, but spectrum analysis, aided by the known velocity of light, has made astronomers agree that 92,890,-000 miles is within 150,000 miles of the correct distance.

The spectra of the stars have been studied as well as those of the sun, and examinations have been made of many hundreds. It has been found from these investigations that while they are not all of precisely the same composition, yet in every case they are of the same general character as our own sun and thus the supposition of earlier days that they were suns, the centers of solar system

resembling ours, has in this Century become a certainty. Some are hotter, some smaller, and some more luminous than others, they differing as do various species of animals. So far off are many of the stars that it is supposed by some astronomers that they were dead and gone perhaps millions of years ago, and are still visible because the light from them that began traveling millions of years ago has not yet reached us. The nearest of these stars is more than 200,000 times as far from us as is the distance from the sun, and the Lick and Yerkes telescope could make visible at least 100,000,000 stars. Though the stars are called "fixed," merely to distinguish them from the planets, yet they are really in motion at a rate faster than that of a cannon ball. Sirius, the most brilliant of the stars, gives us one seven-thousand-millionth of the light that is given by our own sun, yet Sirius is really radiating forty times as much light as is the sun.

The spectroscope has revealed that the many bright patches seen in the heavens on clear starlight nights, and which were formerly supposed to be the wake of very distant stars, are simply gaseous clouds or nebulæ. This was demonstrated by Huggins in 1866, and to him many other discoveries are also due, he having been a leader in spectroscopic astronomy. Some 8,000 nebulæ have been noted and many of them photographed, the first work in this latter direction having been done by Henry Draper, of New York, in 1880. Huggins' spectroscopic researches also made possible the noting of movements of stars along the line of vision, and their actual velocity can be determined in many cases. By means of displacements of spectral lines Huggins discovered that stars are receding and approaching us. Arcturus, the one traveling toward us most rapidly, is coming at the rate of fifty-five miles a second, and Sirius, which is becoming more distant, moves

away at a rate of twenty-six miles per second. Yet in spite of this motion of the stars, it is so slight that the eye, unaided by the spectroscope, could not detect any change in position during a life-time.

It is interesting to recall at the present time that the largest telescope in its day was constructed for the observatory of Madrid, and was placed in the Spanish capital in 1802. To-day the United States has the largest telescope in the world. Important as the size of the telescope is, it must be remembered that it has been shown there are other things of more importance. It is also true that much depends upon the man at the little end of the telescope as well as upon the size of the lens. Yet great telescopes have undoubtedly been of enormous service to astronomy. They have made possible the detection of thousands of more stars than could be seen with the smaller instruments, and it is due to this and photography that we know of the existence of three hundred times as many stars as we did a Century ago. The principle of the telescope has not changed during the Century, and telescopes are still of two kinds, reflecting and refracting. Of the former type the largest is that erected in 1828-45 by the Earl of Rosse at Parsontown in Ireland, which is 6 feet in diameter and 54 feet long. The largest refracting telescope is that of the Yerkes observatory, which was completed in 1895, and has a 40-inch lens, with a length of 70 feet. The refracting telescope is the favorite in observatories and the Lick telescope at Mt. Hamilton, Cal., was the largest until the Yerkes telescope was mounted. It has a 36-inch refractor, while the largest in the Old World is that at Pulkowa in Russia, with a 30-inch lens, built in 1884. The growth in size of refractors is well shown by the fact that the telescope at Pulkowa, built in 1840, and which was the largest in its day, had a refractor of 14.9 inches.

The work of making the lens of these great instruments requires years of toil, for a single error might destroy $40,000 worth of raw material in a 40-inch glass. The rough disks are smoothed down with revolving concave tools, then the surfaces are smoothed and polished with rouge, by hand, no mechanical process being found that will answer the purpose. The lens is tested by looking through it at a star. Handling it for this test is no small task as the lens and its ring weigh about 1,000 pounds. The Yerkes lens is called a 40-inch glass, but its exact diameter is 41 3-8 inches; the crown is about 36 inches thick at the middle and 1 1-4 inches thick at the outer edges. Alvin G. Clark, who made the Yerkes glass, said that it was not his limit. He declared before his death that he could grind a perfect lens 45 inches in diameter. The difficulty in the way of making a larger lens is the weight and flexibility of the glass, as a glass larger than 45 inches would surely bend of its own weight while there are those who believe that the 45-inch glass is impossible. The work of mounting a big telescope is no small engineering feat. The tubes of the Yerkes telescope weigh 75 tons, and the instrument must move with precision, keeping time with the stars. Electric motors are employed for the manipulation of the telescope.

While the greatest astronomical discoveries have not been made with big telescopes, yet these gigantic instruments have done much important service. Bond found Hyperion in 1848 with the Harvard telescope, Lassell's telescope in 1846 discovered the satellite of Neptune, while the resolvability of many nebulæ and their spiral structure was discovered by the great telescopes which have been of great assistance also in the detection of asteroids. E. E. Barnard's discovery of Jupiter's fifth satellite, Burnham's discovery of many double stars and Asaph-

Hall's detection of the two satellites of Mars were made possible by giant lenses.

One of the most important developments of astronomy during the Century has been in the application of photography to the science. The eye of the astronomer gazing at the heavens becomes tired and the longer he looks the less he is able to see. Not so with the camera, which continually records the stars it sees, and is able to detect many that would be unnoticed by astronomers. On this account telescopes are provided with camera attachments and many important discoveries, such as Keley's securing of actual proof, in 1896, of the meteoric constitution of Saturn's rings. Myriads of stars beyond the ken of the most powerful telescope have been revealed by the aid of the astro-photography. One of its most important uses has been in the work of making a photographic chart of the heavens. Millions of stars will be depicted on this chart, and the undertaking is now well on its road to completion. Millions of those detected by the camera were unknown before its use in astronomy. The preservation of these photographic records will be also of importance in showing the movements of the stars to astronomers of future ages. Thus they will be able to acquire new facts in regard to the mighty voyage through space which is being made by our sun and all his system.

ANTHROPOLOGY

If it be true that, as the poet Pope says, "The proper study of mankind is man," mankind owes an immense debt to the Nineteenth Century for its anthropology alone. Hundreds of years ago Aristotle said, "Man is, according to his nature, a political animal," but until the Eighteenth Century there seems to have been no conception of a science of mankind outside of the conventional ground of universal history. The latter part of the Eighteenth Century, so productive of germinal ideas, conceived the idea of a philosophy of the history of mankind, but the science of anthropology scarcely stood on a firm basis until toward the middle of this Century. The comparative method of study has provided the anthropologist with tools with which to solve the most difficult problems. Anthropology is wide in its scope, embracing as it does somatology, psychology and ethnology. The latter branch is that discussed chiefly in this article.

So long as it was believed that the world was only a few thousand years old, history was relied upon to tell the story of mankind. But as the ancient civilizations on the banks of the Nile, the Tigris and the Euphrates have yielded their secrets, it has been found that the world was much older than had been imagined. Then geology stepped in, and assisted by paleontology, revealed that the earth has been in existence for millions of years, and that man has dwelt on it for untold periods of time.

The establishment of the antiquity of man is one of the great achievements of the Century. The first of the Egyptian Kings mentioned on the monuments of the Nile

ANCIENT MOQUI VILLAGE RECENTLY DISCOVERED

valley is Mena or Menes, who was the founder of Memphis. Careful study of the lists of monarchs and of court architects found at Karnak, Sacquarah, and at Abydos has convinced archæologists that Menes lived over three thousand years B. C., at the lowest estimate. Yet at that remote period Egyptian civilization was so highly advanced that Menes began the building of his capital by a mighty feat of engineering—that of diverting the Nile from its channel in order to protect the city against invasion from the deserts on the east. The earliest monuments of Egypt depict a high state of civilization with a complex social order, skillful and beautiful architecture, truly artistic sculpture and painting, and some knowledge of astronomy. Philologists testify that "the oldest monuments of the world show Egypt in possession of the art of writing," and with a highly developed language. These facts, in connection with the knowledge that in the earlier stages of civilization the growth of ideas is much slower than it is later, have led to the conclusion that man lived in the valley of the Nile for many thousands of years before the reign of Menes. Borings in the Nile valley have brought to light pottery and other relics of a simple civilization which were buried so far beneath the surface of the earth that, at the rate of the Nile deposit, it must have taken over eleven thousand years to cover them. And, buried in limestone hills and formations which nature has taken thousands and thousands of years to build, have been discovered evidences of a stone age when man in Egypt, like prehistoric man on any other part of the globe, made his implements and weapons of rudely chipped stone.

In 1799, during the French occupation of Egypt, a French officer of engineers, M. Boussard, discovered in an excavation made near Rosetta, a rude block of black basalt. Soon after, the French fleet was defeated at

Aboukir and the mouths of the Nile were occupied by the English. The "Rosetta stone" fell into the hands of Sir William Hamilton, and in 1802 was presented to the British Museum. This "priceless jewel" of the archæologists furnished the key to the inscriptions on ancient Egyptian monuments and tombs; for, when examined, it was found to bear an inscription in three languages, one written in hieroglyphics, one in demotic, or Middle Egyptian, and the third in Greek. The hieroglyphics, by means of the other two renderings of the inscription, were interpreted with much patient labor by Young and Champollion. The inscription on the basalt steel was in itself not of much importance, being a decree in honor of Ptolemy Epiphanes by the priests of Egypt, assembled in synod at Memphis, for the remission of arrears of taxes and dues owed by that body, and dated 196 B. C. The discovery of another trilingual inscription by Lepsius in 1866, while making researches at Tanis, confirmed the results of the work of the hieroglyphic readers. To-day the most ancient Egyptian inscriptions on monuments and tombs are read, and the life of the people who lived on the banks of the Nile more than six thousand years ago is as open to us as though a thing of yesterday, and the "wisdom of Egypt," so long a sealed book, is ours.

The decipherment of the cuneiform inscriptions of Asia was begun by Georg Friedrich Grotefend, of Hanover. In February, 1802, he submitted to the Academy of Göttingen the first translation of a cuneiform alphabet. By a stroke of genius, Grotefend had, aided by his knowledge of ancient history, deciphered the names of three Persian monarchs, after having observed that certain groups of signs were always preceded by the word "king" which he had identified in a formula in which the signs for "king" frequently occurred. The names of the sov-

ereigns Darius, Xerxes and Hystapes in the orthography of their time furnished only twelve letters of the old Persian alphabet. There was still an infinite variety of characters to be read. Other patient philologists followed in Grotefend's footsteps, each winning renown for himself by deciphering one or two characters. In 1835 Henry Rawlinson applied himself to the work and accomplished the mighty feat of copying and reading the Behistun inscription of more than one thousand lines. Inscriptions in the Persian cuneiform writing were usually accompanied by parallel columns in Median and Babylonian-Assyrian, each of the three languages having a different alphabet. The Archæmenian kings issued their decrees thus in order that they might be read by the three principal nations whom they ruled.

Of the three kinds of cuneiform script the Babylonian-Assyrian was the most important, as well as the most difficult to decipher. The Persian characters are alphabetical, there being only about fifty of them. The Median or Medo-Scythic, as it has been called, is both alphabetical and syllabic, with an alphabet of about one hundred characters. The Babylonian-Assyrian cuneiform script is both ideographic and syllabic. In the development of the script from picture writing the signs passed through many changes. Therefore, there are numerous varieties of Babylonian-Assyrian inscriptions and the student who can read the late Babylonian inscriptions may be totally unable to decipher the late Assyrian; and the early Babylonian is very different from either.

Slow and laborious as was the task of mastering the numerous and varied cuneiform characters, archæologists have had their reward. Multitudes of documents thousands of years old have been brought to light by recent excavations at Babylon, Nineveh and Nippur and through

their perusal the long-forgotten past has yielded up its history and legends.

The appointment of P. E. Botta as French consul at Mosul was a great thing for Assyrian exploration. Through the enterprise and diligence of Botta and his consular successor, Victor Place, the palace of the mighty Sargon was unearthed and explored between the years of 1843 and 1855. This achievement prompted Austen Henry Layard to explore Nineveh, Calah and other ruined cities of Babylonia and Assyria, which he did with marked success, finding a wealth of sculptures and inscriptions. In 1872 George Smith discovered tablets containing the story of the deluge agreeing essentially with the Biblical account of the Flood. These tablets are now in the British Museum.

Nippur, or Niffur, is said to be the oldest city in the world, and well it may be. Some Assyriologists claim that the relics of its ancient civilization recently brought to light, date back to more than seven thousand years before Christ. In 1888 the University of Pennsylvania sent out a scientific expedition under Dr. Peters to explore the ruins of the city of Nippur, near ancient Babylon. The number of tablets, inscribed vases, and the value of the cuneiform texts found therein rivaled the results of the explorations of Layard at Nineveh, and the excavators and explorers thought that they had found the very foundations of the ancient Nippur. Records of the time of Sargon and King Ur-Gur were discovered and a floor or platform was reached which was supposed to be the ground level of the city. It was then thought that the earth had no deeper secrets to reveal. But one of the exploring party suggested that the digging should be continued until either virgin soil or bed rock should be reached. The excavating had already been carried to a depth of thirty-six feet.

It was now continued for thirty feet further. It was found that what had been thought to be the ruins of the ancient city of Nippur were in reality the ruins of a much later city, built above the ruins of an archaic Nippur dating from not later than 6000 years B. C. The inhabitants of this old, old city were in a high state of civilization, which necessarily must have taken centuries for its development. It has been calculated that man must have lived in the valley of the Euphrates for at least ten thousand years before Christ. This need not conflict with the Bible. The system of chronology affixed to the Bible in its margins is not a part of the sacred text, but an estimate made over two hundred and fifty years ago by Archbishop Ussher and others, with the aid of the best light afforded by the scholarship of the day. But since two hundred and fifty years ago how immeasurably has man's horizon widened!

Not only has ethnology, through the labors of archæologists, investigated and studied the buried histories and customs of ancient civilized peoples, but archæology, aided by geology and paleontology, has shown us the life of primeval man. Curiously shaped pieces of stone, crudely resembling weapons, have been found in different parts of the world for thousands of years. As man could find no natural explanation of their remarkable appearance he fancied them of supernatural origin, calling them "thunder-bolts" or "arrows of the gods." During the Middle Ages in Europe some pious folk believed such "thunder stones" to be the "weapons of heaven" and imagined that they had fallen to earth during the battle in which Satan and his host were driven from the abode of light. After the revival of learning, a natural explanation was sought for the origin of these chipped or polished stones, sometimes with droll results. In 1649 Tollius informed inquirers that these stones were

"generated in the sky by a fulgurous exhalation conglobed in a cloud by the circumposed humours." About the beginning of the Eighteenth Century a large weapon of chipped flint was found with the bones of an elephant in a bed of gravel in London. This looked as though the rude stone weapon had been used to kill the elephant in a bygone age. Soon after it was found that the implements of savagery brought to Europe by travelers from far distant lands were very like the "thunder-bolts" found in Europe. Gradually the belief that the "thunder-bolts" were made by primitive man was established. Explorations and excavations made by private individuals in various parts of Europe revealed other chipped or polished flint implements in juxtaposition to bones of beasts or men. In 1847 Boucher de Perthes published a volume on "Celtic and Antidiluvian Antiquities," containing engravings of flint implements and weapons, examples of thousands which he had found in the peat and drift near Abbeville in France. These were found in connection with bones of quadrupeds such as the beaver and bear. Yew trees, firs, oaks and hazels were dug out of the peat in the valley of the Somme, and the whole condition of the valley indicated a series of vast geological changes since the weapons and implements had been left there which must have been at a time when the river system of France was entirely different from what it is now. Similar discoveries were made in other parts of France, in England, in Belgium and in other countries. Lyell, the eminent geologist, visited parts of England, France and Belgium, personally examining many of these discoveries. In 1863 he published his "Geological Evidence of the Antiquity of Man." Since then, implements of man have been found in company with the bones of extinct animals.

When did man first appear on the earth? The remains

of quadrupeds resembling most of our mammals are found in the stratified rock belonging to that part of the tertiary epoch known as the eocene. Fossil anthropoid apes have been found in miocene strata, and it is thought that man may have begun his existence on the globe at the same time. But both miocene and pleocene rocks tell little about man. The gradual cooling of the earth which resulted in the glacial epoch seems to have banished apes from Europe, but many traces of man are found throughout the ice age. There were at least three well defined glacial periods, and there is evidence that man lived in Western Europe in the first of these periods, or early in the quarternary epoch. It has been estimated that the ice age began 240,000 years ago and lasted, including all three glacial periods and intervening milder times, 160,000 years. The first portion of man's existence on the earth is called the palæolithic or ancient stone age. To it belong the chipped flint or other unpolished stone implements. To the neolithic or later stone age belong polished stone axes, hammers, rude pottery and personal ornaments sometimes of jade and of gold. The bronze age shows fine flint implements, pure copper and moulded bronze ones. All prehistoric races seem to have been acquainted with fire, and all except the cave-dwellers of the palæolithic period had hand-made pottery. No definite dates can be assigned to these ages. Roughly speaking, the early stone age lasted throughout the glacial age. The later stone age lasted in Europe until a comparatively recent period, being followed by a short bronze age which merged gradually into an iron age. But there is no definite division between the ages either in time or country.

During the high civilization of the Greeks and Romans the tribes on the shore of the Baltic Sea were still in the early stone age, and the Finns, who to this day

have made less progress than any other European people, were savages of the most primitive type. Tacitus describes them as "abjectly poor and wonderfully savage. They have no homes," says he, "no arms; they dress in the skins of wild beasts; they sleep on the bare ground; they have no iron, and their arrows are tipped with bone. Like the men, the women live by hunting, accompanying them in their wanderings and sharing the prey. They weave nests from the branches of trees to cover their little children. These are the homes of the young and the resting places of the old; still they consider such privations preferable to the work of tilling the fields, building houses and, alternating between hope and fear for themselves and those belonging to them, careless of man, regardless of the gods, they have reached that most desperate state where they feel no need of prayer."

Very like this was the state of primitive man. He lived only for the day and took no thought for the morrow. A shelter of boughs was his only home, unless he was fortunate enough to find a cave in which to take refuge, and for this he was probably obliged to do battle either with some wild beast or his fellow man before he could occupy it. Like the North American Indian, he wandered over the earth, following the game on which he depended for food for himself, his mate and their young. His pairing was usually permanent, and his offspring he cared for to the best of his ability, except in the case of the feeble and sickly, who were often slain without mercy. It was a case of the survival of the fittest. He had no home to protect, no property, beyond his weapons, to defend; no sympathy outside of his little family group; and the tribal state, which grew from the natural increase of families, was a decided advance in his social progress.

It was a wonderful discovery for ethnology that people

in the same stage of development are almost exactly alike without reference to the time or place in which they live. Thus the Australian and South African races of savages, until lately to be seen in a primitive state, furnished data for comparative ethnology and aided in determining the characteristics and condition of primitive man thousands upon thousands of years ago.

The Bureau of Ethnology of the Smithsonian Institute began to publish annual reports in 1879. For many years individual students and explorers, as well as scientific societies, had collected and published information about the aborigines of America, and the world was comparatively well acquainted with the appearance, customs and habits of the red men. But all attempts at classification had been founded on somatological characteristics. Such classification was pronounced by the Bureau of Ethnology "utterly useless in practical ethnic work." Therefore the Bureau began to develop another system based on language. "Similarity in language generally accompanies similarity in tribal organization and law, while similarity in language and law is commonly connected with similarity in beliefs and arts," says J. W. Powell, director of the Bureau of Ethnology. This discovery of the connection of language with social organization, law and beliefs led to the systematic study of the institutions and ceremonials of the Indians, and brought to light complex organizations and elaborate religious beliefs, including the explanations of many singular customs and curious or beautiful myths. The discoveries of the Bureau of Ethnology are turned to account in grouping the Indians on reservations. Those who are bound together by ties of language associate much more amicably than those whose likeness is purely biotic.

An especially interesting department of the work car-

ried on by the Bureau of Ethnology is the study of the relics of prehistoric inhabitants of our land. These left behind them not only stone and copper weapons, implements, ornaments and pottery, but mammoth earthworks and graves, such as the artificial hillocks of the people whom, for lack of a better name, we call the Mound Builders, and forsaken habitations such as the homes of the Cliff Dwellers. The Mound Builders are supposed to have lived over two thousand years ago, but, to-day, their earthworks still exist in large numbers in the river valleys and plains which they inhabited. In Ohio alone there are nearly ten thousand artificially constructed mounds, and in the neighborhood of Trempealeau, Wisconsin, almost two thousand. But the mounds are not confined to a few states, being found in almost every section of the Union, and in Mexico. They are rarer in British America. They vary vastly in size and in shape. Many of them exhibit mathematical regularity, being built in geometrical figures, others are shaped to resemble animals, including man. The "Serpent Mound" in Ohio is gigantic, being more than one thousand feet long, and is regarded by archæologists as the most remarkable of all the structures built by this singular people. Through the efforts of F. W. Putnam, the eminent archæologist, the Serpent Mound was purchased by the American Association for the Advancement of Science and presented to the Peabody Museum of Harvard University. Soon afterwards, the trustees of the museum made the additional purchase of seventy acres of land immediately surrounding the mound, and the whole was laid out as a public park. The serpent measures 1,254 feet in length from the tip of the upper jaw to the end of the tail. The jaws are open as if to swallow the oval commonly known as the egg. Viewed as a whole, it appears as though the huge python were creeping for-

ward to seize the oval, which gives it a weird lifelike appearance. Such structures as the Serpent Mound are called "effigy mounds." Many curious "effigy mounds" have been discovered, some of them representing men, panthers, wild cats, lizards, raccoons, tortoises, spiders, and squirrels.

Many of the earthworks of the Mound Builders are breastworks and fortresses, and it has been found that their builders, who lived so long ago, were skillful enough to erect for defence walls, redoubts and other fortifications, choosing their sites with the acumen of trained engineers. Archæologists have lately discovered that their fortifications are connected by deep trenches and admirably constructed secret passages. Some of the high mounds built on hill tops were evidently used as observation posts from which to signal or to spy on the movements of enemies. Excavation and exploration are revealing more and more about these interesting people, but, in spite of the numerous relics unearthed from their mounds and the patient investigations of archæologists, many of their secrets seem to be lost forever.

The wonderful structures of Colorado, Arizona, New Mexico, and Utah, known as the cliff-dwellings, are still a puzzle to archæologists. Why did these prehistoric people build so high? Science has no better answer than that they builded because they found the caverns in which to build. However, this answer seems insufficient since the Pueblos, who seem to be descended from them, are much nearer the level of the ordinary habitations of men. Traditions in all tribes from Oregon to Mexico agree in the story of a great flood, ages and ages ago, which but few escaped, and the question arises whether the Cliff Dwellers, like the builders of the Tower of Babel, may not have intended to build so high as to avoid such danger in future.

These singular habitations are found within an area of three hundred miles square in the steep cliffs which border the canyons of that region. The rock of the cliffs runs in layers with ledges and galleries varying from a few feet in extent to a thousand and fifty feet wide. On these ledges the Cliff Dwellers erected their homes. The houses vary much as do human dwellings everywhere, some being small adobe structures like huge swallows' nests, other substantial stone houses with three or four stories, though the stories are rarely more than six feet in height, others yet show the ruins of towers. The stone edifices are built of blocks of stone cut into regular shape and held together by adobe cement. The roofs are constructed of a layer of pine or cedar poles crossed by another of small sticks and covered with adobe cement into which vegetable fiber was pressed. Six by six to eight by ten feet was the usual size of the rooms.

Estimates place the period at which the dwellings of the Cliff Dwellers were abandoned at thousands of years ago, but the relics found in their graves, their dwellings, and refuse heaps show them to have attained a degree of civilization as high as that of the Moquis, or even the Aztecs. The skulls show fully average brain capacity. The mummies prove that the men reached a height of six feet, while some of the women stood five feet, seven inches. The skull of one woman has soft reddish-brown hair still adhering, which is neither wiry like the Indian's nor woolly like the negro's, but is as fine and as straight as that of a Caucasian. Among the relics of the Cliff Dwellers are spear-heads, arrows and throwing sticks, basket work which equals anything done by modern workmen and, most wonderful of all, a robe of feathers and fur in quaint pattern and coloring. Their wooden vessels were painted with a resinous substance which filled the pores of the

wood and hardened, rendering them waterproof. In the grave of one woman were found several bracelets of turquoise beads and a small pouch of skin containing threads of yucca fiber with two finely pointed prickers. Their bone needles and spoons show clever workmanship, and their pottery closely resembled that of the Pueblo Indians of New Mexico.

From their eyrie-like abodes the Cliff Dwellers are supposed to have descended after their number became much greater. Then were built the rounded towns on plains or table lands. To them were applied the ancient architecture of their forefathers. High perpendicular walls, artificially constructed, took the place of the sheer walls of the canyons, and from them houses were built, descending in terraced stories exactly as houses had been built from the natural walls of canyons. All the dwellings faced the open court. Thus the court took the place of the canyon which the ancient dwellings overlooked. Not only were the main features of the cliff-dwellings transferred to the rounded towns of the plains, but inconspicuous details which had been admirably suited to the exigencies of the cliffs were exactly copied on the plains with no apparent reason except the prompting of long usage.

The great difference in the houses of the Cliff Dwellers gives rise to the belief that there were two distinct races of these peoples. Frank Hamilton Cushing, who has lived among the Zuni Indians for years, says that the "cave dwellings," usually further down on the cliffs, are of an older type than the "cliff-dwellings." The "cliff-dwellings" are rounded, while the "cave-dwellings" are rectangular. The Zuni Indians are supposed to be descended from a union of the two kinds of Cliff Dwellers who came together after they had built their towns on the plains. This is attested by the fact that the Zunis have among their

wealth of legends one in which is told of the coming together of the "People of the Midmost" and the "Dwellers-in-the-towns-builded-round." Gradually the building customs of the "People of the Midmost" who builded "square" superceded the customs of the people who builded "round." So, when the white man came to America, he found the Zunis dwelling in square towns, and only ruins bore witness to the round ones.

The Zunis are particularly interesting to study, being more like the archaic peoples of America than any other of the Indians, even among the Pueblos. Although more highly developed in many ways than any of the aborigines, they retain many of the ancient myths and customs of their ancestors.

A fruitful field of investigation to the anthropologist is that of folk-lore. Says Dr. Daniel G. Brinton: "The stories, the superstitions, the beliefs, and customs which prevail among the unlettered, the isolated, and the young, are nothing else than survivals of the mythologies, the legal usages, and the sacred rites of earlier generations. It is surprising to observe how much of the past we have been able to construct from this humble and long-neglected material."

A result of what is called mankind's psychical unity is the tendency to evolve at a like stage of intellectual development like ideas and fancies. Granting the analogy between the life of an individual and the history of mankind as a whole, it will be seen that the ideas and fancies of a race at an early stage of development must resemble those of a child, and that the imaginings of a child must resemble those of the savage of to-day, and those of the savage of to-day must be like those of primitive man, no matter where or when he lived. All this is well borne out by evidence. Children's games and stories contain many

elements of savage customs and folk tales, and the savage folk tales of to-day betray a close resemblance to the earliest myths and legends of which we have knowledge.

Researches of the ethnologist and archæologist have thrown much light upon the subject of philology, and its comparative study has been almost entirely a growth of the Century. Franz Bopp, of Mainz, is known as the father of the science, and his reputation was made by his "conjugation system" published at Frankfort in 1816, in which he traced the history of the verb inflections of the Greek, Latin, Old Persian and Teutonic as compared with the Sanscrit. In later works he traced their grammatical forms to a common origin in a lost Indo-Germanic speech. In connection with the study of languages it is interesting to note the predominence of the English tongue in the world to-day. When Shakespeare and Milton wrote it was spoken by less than 6,000,000 of people. At the beginning of the Nineteenth Century, French, German, Spanish and Russian each had wider currency than English, there being but 20,520,000 English speaking persons. But in 1890 English was the tongue of 111,100,000 persons. Its proportion of the whole had increased from 12.7 to 27.7. German, the second on the list to-day, is spoken by 75,200,000 beings, a proportion of 18.7—the same as in 1801. English is rapidly becoming the polite language of Europe and it is well known that those engaged in the Asiatic trade find it by far the most useful tongue to master for purposes of commerce.

EXPLORATION AND DISCOVERY

As an era of exploration and discovery the Nineteenth Century vies with that of which Columbus was the central figure. Some idea may be obtained of the vastness of the progress that has been accomplished, by comparing a map of the world a hundred years ago with one showing our present knowledge of the earth's surface. No land has been too remote or forbidding to deter the restless Ulysses of the present Century from an exploration of its profoundest mysteries. Probably the most magnificent and far-reaching result of this intrepid spirit of adventure has been the opening of what has, since the dawn of history, been known as the "Dark Continent." In the beginning of the Century Africa was a blank from 10 degrees north latitude to the confines of Cape Colony.

Before attempting to recount some of the many wonderful discoveries of the era that began with Livingstone and extends down to the present day, it might be well to mention a few of the minor expeditions that have contributed their assistance toward the solution of the African problem. In 1816 Captain Tuckey succeeded in exploring the Congo as far as the first rapids. In August, 1827, Clapperton, in company with Denham, made his famous journey from Tripoli to Lake Chad, and crossed Africa from the Bight of Benin to Sokoto. In 1820-27 a survey of nearly all the west and east coast was made by Captain F. W. Owen, and the north coast by the Beecheys. In 1840 Abyssinia was explored by Dr. Beke, and in 1843-6 Mansfield Parkyns and Chichele Plowden made egress into this forbidden land by way of the Nile. In 1846 John

CAPTAIN WILKES DISCOVERS THE ANTARCTIC CONTINENT

Petherick traversed the territory from Keneh to Kosseir, and in 1853 entered the land of the Jur. James Richardson was the first European to enter Ghat, and after exploring Fezzan turned to Tripoli in 1850. An expedition, 1851-54, under Dr. Barth, explored the Central Sudan States, the Niger, Shari and Binue and the territory watered by them, and visited Timbuktu. In 1850 Francis Galton made a 2,000 mile journey through the country of the Damara and the Ovampo.

In 1840 the immortal Livingstone, with whose name African exploration is probably more closely associated than with that of any other traveler, went to South Africa as a missionary. The year 1847 found him settled in the very interior, whence, in 1849, he accompanied Oswell and Murray on an expedition in search of Lake Ngami, about which he had obtained some information from the natives. On August 1st he discovered the magnificent sheet of water, and during the few days following explored its borders, afterward making an extended voyage down its outlet, the Zouga. In 1852, after having sent his family to England, Livingstone commenced a journey of discovery that won for him the plaudits of the entire world. For four long years he traversed South Africa from the Cape of Good Hope, passing through Tete, descending the Zambesi to the sea, traveling in all an estimated distance of 11,000 miles. For this great achievement he received the Victoria Gold Medal of the Geographical Society, and when he visited England in 1856 he was received with distinguished honors. In the spring of 1858 he returned to Africa and (accompanied by Mrs. Livingstone) began his famous Zambesi expedition, which continued until 1864. After following the course of the great stream for a long distance he turned off toward the North and explored the beautiful Lake Nyassa, which he discovered in September,

1859. The death of Mrs. Livingstone at Shupanga, April 27, 1862, was a sad ending for a long succession of brilliant accomplishments, and in 1864 Dr. Livingstone returned to England. He immediately made preparations for another expedition, and in April, 1865, he left his native land, never to return. Nothing was heard from him for a year, and in March, 1867, it was reported that he had been assassinated by the natives. Only occasional stray bits of news regarding his movements were received by the outside world until 1869. Then followed a long silence of two years' duration. Public anxiety had by this time reached a fever heat, and the New York Herald sent out its correspondent, Henry M. Stanley, to search for the missing man. Stanley reached Ujiji in the autumn of 1871. He there found the lost Livingstone alive and well, and received from him an account of his long wanderings and marvelous discoveries. Livingstone and Stanley together now made an exploration of the north end of Tanganyika. In March, 1872, Stanley returned to England, and Livingstone proceeded South to Bangweolo, where he died. In his career as an explorer, Livingstone traversed some 29,000 miles of African soil, most of it new, and he laid open nearly one million square miles of territory that was previously unknown and which had appeared on the map as an absolute blank.

While Livingstone was at work in South Africa, Burton and Speke, Grant and Baker, were exploring the magnificent domains of the Upper Nile country. In 1861 Speke and Grant reached Unyanyembe, and the two succeeding years were spent in a march northward to the Victoria Nyanza, the vast inland fresh water lake discovered by Speke in his expedition with Burton in 1857. The outlet of the Nile at Ripon Falls was discovered, and in February, 1863, they met Sir Samuel Baker at Gondokora

on the White Nile. There was great joy among the travelers when they met on the shores of this classic stream, and there were many congratulations exchanged. Speke and Grant by their discovery of the main source of the Nile had solved a puzzle that had been exercising the imaginations of geographers since the dawn of history. Sir Samuel related his rediscovery of the Muta Nzige of Speke and of a second vast sheet of water, to which he gave the name of Albert Nyanza. In 1874-79 Gordon Pasha cleared up still further the mystery of the Upper Nile, and obtained much valuable knowledge of the territory on either side of the river. In 1887-9 Stanley headed an English expedition sent out to the relief of Emin Pasha, which resulted in further knowledge regarding the hydrography of the Nile and the Congo.

The expedition which fixed Stanley's fame as one of the greatest explorers the world has ever known was that which began in 1875, when he circumnavigated the Victoria Nyanza, visited Uganda, marched across an unknown country to the river Lualaba, on which he embarked in November, 1876, not knowing where the mighty torrent would lead him. He traveled a distance of 1,800 miles, and when he reached the mouth of the river, in August, 1877, it proved to be the Congo. This was the most important discovery that had ever been made in the exploration of the dark continent. Its consequences were of vast political and commercial importance, among them the founding of the Congo Free State.

Although the opening of Africa has been preëminently an English undertaking, much notable work has been done by French and German expeditions. One of the most remarkable exploits is that of Commander Monteil, a Frenchman, who early in 1893 completed a journey of 4,400 miles, three-fifths of it in humid tropical Africa, and

two-fifths in the thirsty desert. He is the first white man to cross from ocean to ocean the country lying below the great northern bend of the Niger River, and he is the second white man to reach Lake Tchad from the Atlantic Ocean. The expedition in 1893 of Lieutenant Von Gotzen across the forests of Central Africa, from sea to sea, was a noteworthy one from a geographical standpoint. In the year 1861 Gerhard Rohlfs began his explorations. Disguised as a Moorish physician, he entered the Kingdom of Morocco, practiced for a time with great success at Fez, and subsequently visited all parts of the country north of the Great Sahara. During a journey to the oasis of Tafilit, in the Sahara, he was attacked by the leaders of the caravan he had joined, robbed, severely wounded and left as dead by the maurauders. A band of passing dervishes found him nearly dying with thirst and loss of blood, and, binding his wounds and giving him a supply of water, left him to continue his journey unmolested. Undaunted by this terrible experience he undertook to reach the oasis of Tuat, which had never been visited by a European. He succeeded in this remarkable venture, secretly measured and mapped it, and then made his way to Tripoli by way of the more northerly Oasis of Chadames. This journey counts among the most important and daring explorations of the Dark Continent.

To name all the men who have within the past forty years devoted their lives, and, in many cases, sacrificed them, to the details of African exploration, would be an impossible task, and to make a selection would be invidious. Scores of scientists and brave missionaries have laid down their lives in attempts to probe the mysteries of the interior, and countless minor expeditions have gone into the heart of the Dark Continent never to be seen or heard of again.

The first man to attempt the solution of the "polar problem" in the present Century was Captain William Scoresby, an Englishman, who pushed his way through terrible difficulties until he reached a latitude of 81 degrees 12 minutes, 42 seconds, on the north of Spitzbergen. In 1818 the British Government sent out two expeditions. One, under Captain James Ross and Lieutenant Edward Parry, was dispatched to Davis Straits, and the other, under Captain Buchan and Lieutenant John Franklin, to Spitzbergen. The latter expedition met with misfortune before it had reached the latitude attained by Captain Scoresby, but the former, with the utmost exertion, succeeded in rediscovering Baffin's Bay, passing by way of Lancaster Sound 400 miles westward, or about half way to Behring Strait. In 1821-3 Parry made a second journey, discovering the Fury and Hecla Straits. In a third attempt (1827) he succeeded in attaining the latitude of 82 degrees 45 minutes north of Spitzbergen, which was no farther than whalers had penetrated in former years, with scarcely a hindrance. He quit his ship, the Hecla, on the northern coast of Spitzbergen and betook himself to his boats. When he had reached 81 degrees, 13 minutes, he encountered difficulties that compelled him to convert his boats into sledges. After a long, perilous journey toward the North he discovered that the ice on which he was traveling was moving Southward as rapidly as he was advancing North, and that he was in the very same latitude as when he started. In the meantime Lieutenant Franklin had started on another expedition, in 1819, and had succeeded in traversing a long stretch of the coast of Arctic America, passing by the Saskatchewan and the Barren Grounds as far as the Coppermine River, which he followed and explored for 500 miles. In 1826, accompanied by Dr. Richardson, his companion in the former

expedition, he descended the Mackenzie River and explored the coast of the continent through 37 degrees of longitude, pushing as far West as 160 miles from Point Barrow, which had been reached from the West in 1826 by Captain Beechey. Meanwhile the viking spirit of Captain Scoresby had not been slumbering. In 1822 he had penetrated the ice-barriers of Eastern Greenland, and had surveyed the coast line from 75 degrees to 69.

The most important of the early Arctic expeditions was that commanded by Captain John Ross and his nephew, James C. Ross. The ship Victory, which carried the party, left England in 1829, entered Barrow Strait, and into the Gulf of Boothia—named in honor of Felix Booth, the patron of the expedition. The projecting peninsula on the left, also named Boothia, was thoroughly explored, as was also King William's Land. On June 1, 1831, a wonderful discovery was made. The Magnetic Pole, the ancient mystery of mariners, was located in the western part of Boothia. For a long time the Rosses were thought to have perished, and in 1833 a relief expedition was sent to their rescue, but before reaching them they had been picked up by a whaling vessel in Barrow Strait, having had to abandon their own ships. In 1837-39 Simpson & Dease, of the Hudson Bay Company, completed the tracing of the coast line westward as far as Point Barrow and eastward to the Castor and Pollux River. The entire outline of the Northern coast of America was not known, however, until 1853, when Dr. John Rae took up and completed the work begun by the Hudson Bay Company people and discovered King William's Land to be an island.

In June, 1845, the indefatigible John Franklin, who had been knighted in 1829 in recognition of his distinguished services as an explorer, was given command of the Erebus and the Terror, and instructed to attempt to dis-

cover a practicable northwest passage to India. With the blare of trumpets and the adulations of a whole nation ringing in their ears, the expedition left England to meet one of the most tragic fates of modern times. The last that was seen of the vessels was in July of the same year. No news of the party having reached England, a relief expedition was sent out which returned without finding a trace of the lost ones. Between that and 1854, twenty separate expeditions, at the cost of a million pounds sterling, were sent from England and America in hope of finding—if not survivors—at least traces of the missing crews. The task seemed hopeless, but after long and persistent endeavors on the part of the British Government, of Lady Franklin and of private explorers, the mystery was finally solved by the expedition of McClintock, in 1857. This steamer made the melancholy discovery that Sir John Franklin died June 11, 1847, off the Northwest coast of King William's Land, and that on April 22, 1848, the Erebus and the Terror were abandoned in the ice. The officers and crew, 105 souls in all, under Captain Crozier, reached King William's Island, whence they attempted to make their way to the Hudson Bay Company's stations. From information gleaned from the Esquimaux, and by subsequently discovered relics of the party, it appears that the poor men fell, one by one, on the way, dying of cold and starvation, and that very few of them ever reached the mainland. The relief expeditions that were sent out with the hope of succoring the ill-fated Franklin party have indirectly led to the richest geographical results. Among the most important of these expeditions is that of Dr. Kane, who sailed from New York, May 30, 1853. Dr. Kane, three years previously, had accompanied Lieutenant De Haven in an expedition for the same purpose. The disappointment that had attended the

return of the unsuccessful American and English expeditions only increased the public desire to ascertain the fate of Franklin, and Dr. Kane shared in this anxiety to the extent of contributing his entire fortune to the fitting out of the Advance. The brave officers and crew were unsuccessful in obtaining any trace of Franklin and had to abandon their ship in the ice and travel with sledges and boats for eighty-four days, until they reached the Danish settlements of Greenland. The stories of the suffering and discoveries of this little band of adventurers are among the most thrilling in the history of Arctic exploration. On his return, in 1855, Dr. Kane was awarded gold medals by Congress, by the Legislature of New York and by the Royal Geographical Society of London. He also received the Queen's Medal given to Arctic explorers.

Previous to 1879 Arctic expeditions had left the region north of Behring Strait comparatively unexplored, and on the 8th day of July of that year, the ill-fated Jeannette sailed out of the Golden Gate at San Francisco bound "for that strange land from whose bourne," it may almost be said, "no traveler returns." The Jeannette, formerly the Pandora, a gunboat, was officered and manned from the United States Navy. There were thirty-two souls on board, under the command of Captain De Long, and the ship was provisioned for a three years' cruise. The ship proceeded by way of St. Michaels, Alaska, and thence to Wrangle Land, where the ship was frozen in on the night of September 20. Then came a period of twenty-one months drift in the ice pack, and during the first five months only forty miles was made. Yet several islands were discovered and named. On May 16, 1880, Jeannette Island was sighted in latitude 76 degrees, 47 minutes N.; on May 27, Henrietta Island, 77 degrees, 8 minutes N.; also Bennet Island, in latitude 76 degrees 38 minutes N.

For two long years nothing was heard of the Jeannette, and during all this time she was drifting helplessly and surely to destruction. On the 11th of June, 1881, the end came, and the ship was crushed to dust beneath a mountain of ice from one of those sudden upheavals that had so often threatened her during her long sojourn upon this floating island. Fortunately, the catastrophe had been anticipated, and the crew had been divided into three parties, which put out in small boats. They were then in latitude 77 degrees north, near New Siberia Island, 500 miles from the mouth of the Lena river. The boats succeeded in keeping together until the night of September 12, when a terrible storm sent them drifting in different directions toward the Siberian coast. The boat containing Lieutenant Chipp and his crew was never heard from, but the boats of Captain De Long and Chief Engineer Melville landed at points near the mouth of the Lena. It was a barren, desolate shore that De Long stepped upon, with no trace of its ever before having been trodden by a human being. Melville's crew was more fortunate in finding a landing place, and they immediately instituted a search for their superior officer. Many weeks afterward tracks were discovered, and with the assistance of native guides, the searching party were at last successful in finding the location of the last bivouac. The bodies of De Long and his companions were found lying about the charred embers of the fire they had built. De Long's diary was by his side, his pencil grasped in his frozen fingers, showing that the delicious rest of that sleep which precedes death by freezing had overtaken him in the act of making an entry in the sad record of his sufferings. On April 7, 1882, the remains of the whole party were laid in one grave, with a pile of stone and a wooden cross to mark the spot. During the winters of 1882-3 and 1883-4 the bodies were

transported across Siberia on dog sleds, a distance of 5,761 miles, to the eastern terminus of the railroad to Moscow, whence the funeral cortege moved on to America, special honors being paid to it all along the route.

The next important Arctic expedition was that undertaken by A. W. Greely (then a lieutenant in the United States Army), who started in the ship Proteus in the summer of 1881, with twenty-five explorers and provisions to last a little over two years. Headquarters were made in Discovery Harbor in August of that year, and the Proteus returned to the United States. The chief object of the expedition was to establish a scientific international polar station in Lady Franklin Bay, as recommended by the Hamburg International Polar Commission of two years before, and to this end excursions were made into the surrounding country to obtain the true position and outline of Grinnell Land. Captain James Lockwood was entrusted with the most important field work of the expedition. In March, 1882, in company with Sergeant Brainard, they set out on a journey that fixed Lockwood's fame as an Arctic explorer. They crossed Robeson channel to Newman Bay on dog sleds with the thermometer ranging from 30 to 55 degrees below zero. After reaching Cape Bryant, on the north coast, they sent back all their attendants except one Esquimaux servant, and proceeded northward to an island in latitude 83.20, less than 350 miles from the pole, where, on May 15, Lockwood unfurled to the breeze the United States flag, exultant in the thought that it waved in a higher latitude than had any flag before. The little party returned to Fort Conger June 17, the journey having occupied sixty days and covering a distance of 1,069 miles. The expedition was rich in scientific and geographical results. The recorded boundary of known land had been extended twenty-eight miles nearer the pole,

and 125 miles of hitherto undiscovered coast line mapped out. As previously arranged with the Government, the Neptune was sent out with fresh supplies in 1882 and the Proteus in 1883. Neither of these vessels reached Discovery Harbor, and the Proteus was crushed by the ice and sunk. Their supplies running low, the expedition abandoned their quarters and reached Cape Sabine in October with supplies for only two months. Their sufferings during the succeeding year were intense. Sixteen died of starvation, among them the brave Lockwood, one was drowned and one shot to death for stealing food from the commissary stores. In the meantime the public anxiety had grown intense, and the United States fitted out another relief expedition. Captain Schley (since the famous commodore of the American-Spanish war), with three ships, Thetis, Bear and Alert, reached Cape Sabine June 22, 1884, and took off the seven survivors, then at the point of death. Lieutenant Greely was unable to appear in public for some time after his rescue, but as soon as he was able, he was received with enthusiasm, not only in his own country, but abroad.

The next American to strive for the honors of Arctic discovery was Lieutenant Robert E. Peary, United States Navy, who was sent out in June, 1891, by the Academy of Natural Sciences of Philadelphia. The object of the expedition was to explore the north and northwest coasts of Greenland from the land side. Lieutenant Peary was accompanied by his wife and a number of scientists detailed by the Academy. The expedition sailed June 6, on the Arctic whaler Kite, Captain Richard Pike commander. The journey was unmarked by fatalties, and the explorers succeeded in attaining 83 degrees, 24 minutes, a still higher latitude than reached by Lockwood and Brainard. In 1893 Peary made a second expedition,

accompanied again by his wife and a party of scientific men. After sending home the vessel, the party went into camp on the west coast of Greenland, where a daughter was born in September. The winter of 1893-94 was spent in preparations for sledge exploring. On March 6 they set out on a journey which resulted in the survey and mapping of 150 miles of coast line hitherto unknown. A relief auxiliary expedition, headed by Henry S. Bryant, and including Professor William Libbey, of Princeton, as geographer, Professor T. C. Chamberlain, of the University of Chicago, as geologist, and Dr. Axel Ohlin, of Sweden, zoölogist, opened communication with Peary on August 1, and reached Falcon Bay August 20. They returned August 26, leaving only Lieutenant Peary and his two volunteers, Lee and Henson, to complete their explorations next season. A second relief party brought back the explorers to the United States in 1895. The amount of knowledge which the Peary expeditions have contributed to science is incalculable. His survey covers 1,000 miles of the coast of Greeland. The direction of the coast, the bays indicated and the islands discovered, make an entirely new map. Eleven islands, not on previous charts, have been marked accurately, and 100 glaciers have been located where only ten were known before. They did not get as far north as their predecessors, but the real success of the expedition in scientific results surpasses all previous and later Arctic attempts.

The Jackson-Harmsworth expedition of 1894-97, which left England in the whaler Windward, solved some most interesting geographical problems. The northern coasts of Franz Joseph Land were accurately determined, and the much vexed problem of Gillies Land was decided. It is now quite clear that this land does not lie where geographers have been in the habit of putting it. The

map of British Franz Joseph Land was practically completed, and the new map entirely revolutionizes old ideas of the territory. Instead of a continental mass of land, as was long supposed, there is a vast number of small islands, to the north of which is an open sea, the most northerly open sea in the whole world, and which has been named the Queen Victoria sea.

This long catalogue of daring Arctic adventures was brought to a fitting climax by the return of Dr. Fridjof Nansen, the Norwegian explorer, whose triumph it is to have gone nearer the pole by 200 miles than any of his predecessors. On June 24, 1893, the wonderfully constructed Fram left Kristiana. The success of the expedition was no doubt due largely to this vessel, which was built on a plan calculated to resist the stupendous power of crushing ice floes. On the 10th of September the northern point of Siberia had been safely rounded, and the Fram pushed eastward toward the New Siberian Islands. On September 25, at a latitude of 78 degrees, 45 minutes, the vessel was frozen in about 150 miles noth of the western part of these islands. Then began the routine of the drift. The ship was arranged for the winter, and a windmill erected for electric service. This drift continued until September, 1894, when Dr. Nansen concluded that he and a companion would attempt a sledge journey over the ice by which he could explore further to the northward. On March 14 a start was made with three sledges and nine dogs each. On the first day only nine miles was made, the temperature ranging from 40 to 45 below zero. They pushed on by these slow stages until April 8, when a chaos of ice blocks barred the way. The latitude attained was 83 degrees, 13 minutes, 6 seconds, in east longitude 95 degrees. Progress was so slow and with no sign of improvement, that the gigantic task of covering the 200

miles intervening between that point and the pole had to be abandoned, and it was decided to turn to the southward. Then began a terrible struggle for life. Exhausted nature began to assert itself, and on the 12th of the month the pair slept so long that their watches run down. As the dogs began to die from exhaustion they were killed and fed to the survivors. At first some of them refused to eat it, but hunger soon destroyed all scruples against canine diet. Not until the 24th of the following July did the sight of land gladden the eyes of the weary travelers, and then it was but a barren snow covered shore; yet twenty-two days of terrible struggle elapsed before the land was reached. Almost impossible ice, lanes and pools had to be crossed on short rations, and Nansen writes: "Inconceivable toil. We never could go on with it if it were not for the fact that we must. On the 7th open water was reached. The two surviving dogs were regretfully killed, and after many struggles with the ice along shore, on the 15th of August the pair set foot on the solid earth for the first time in two years. It was now too late for them to attempt to travel further south, and winter quarters were made on one of the islands of the Franz Joseph archipelago. Here in dull misery and squalor, the winter was passed in a half comatose condition. They ate and slept and kept a few observations going." Nansen's journal shows no complaints or repinings, although for more than two years no food except whale blubber had passed his lips. On the 19th of May they left their winter lair. After many vicissitudes and dangers, on June 17 Nansen heard the bark of a dog and in a few moments was shaking hands with the members of the Jackson-Harmsworth expedition. Their task was ended and the victory won. The journey of Nansen and Johansen from the Fram to their winter quarters was, in round numbers about 500 nautical miles,

and the distance made averaged three miles a day. The distance from their winter quarters to the nearest frequented harbor in Spitzbergen was 540 miles. Had Nansen not met with the English expedition, the result in the end must have been disastrous to him and his companion. Truly fortune favors the brave.

Of the daring Professor A. S. Andree, of Stockholm, there can nothing be said. Under the patronage of the King of Sweden and the endorsement of the Czar of Russia, he started for the pole in a huge balloon in May, 1897, and up to the present time nothing authentic has been seen of or heard from him.

In this great international race for the north pole, the search for the south pole has not been neglected. Antarctic exploration began with the year 1820, when the Russian expedition, under Bellinghausen, discovered the islets of Petra and Alexandria. In 1821 Captain George Powell discovered the South Orkneys. In 1831 Captain John Biscoe discovered Enderby's Land, but did not get within twenty miles of it by reason of the ice. He also discovered Adelaide Island and landed on it. In 1838 Captain John Bellew and Captain Freena discovered a group of volcanic islands, one peak of which rose to a height of 12,000 feet. In 1839 Dumont d'Urville discovered Terre Adelie and Cote Clair, two islands. It remained, however, for Captain Charles Wilkes, commanding the United States exploring expedition during the years 1838-42, to really discover, explore and make certain the existence of land around the southern pole. Towards the close of December, 1839, Captain Wilkes and his squadron, consisting of the United States flagship Vincennes, the Peacock, the schooner Flying Fish and the brig Porpoise, set out for New South Wales and by January 1, had reached latitude 43 degrees south. It was mid-

summer weather for that region and preparations were made to secure the interior of the vessels from cold and wet, which inevitably lay in store for them. The bold navigators were sailing into a sea of mystery and doubt and no one knew what was before them. On January 3 the fog became so thick that the flagship's horns were not heard by the other vessels and they became scattered. On the 10th the first icebergs were met by the Vincennes, and on the 11th she was unable to proceed for the impassable barrier of bergs before her. In the meantime the Peacock had reached Macquerie Island, and the Porpoise was sighted not far off. For many days thereafter the three vessels of the squadron skirted westward along the ice barrier. On the 19th the officers of the flagship distinctly saw high land, leaving no possible doubt of the discovery of the Antarctic continent. Soundings brought up mud and great bowlders were found on the icebergs. All efforts, however, to pass the great perpendicular wall of crystal were futile, and after many narrow escapes from being ground to powder by the ice, days of slow creeping through mist and fog, the three ships pointed for the Auckland islands.

The expedition sent out by the British Government in 1839-43 in the Erebus and Terror, under Captain (afterward Sir) James Ross, was rich in geographical results. The two vessels which were destined, a few years later, to carry the ill-fated Franklin party to its doom, succeeded in reaching the latitude of 78 degrees, 11 minutes S. in February, 1842, without mishap. In the first year Kerguelen Island was surveyed, and in the following year Victoria Land was sighted in 70 degrees S. latitude. Proceeding southward along the coast capped with lofty mountains, an active volcano, Mt. Erebus, 12,400 feet, was sighted in latitude 77 degrees, 30 minutes; also an extinct volcano, Mt. Terror, 10,900 feet, but owing to im-

penetrable ice barriers, further progress was impossible. What was immediately beyond this high, perpendicular cliff of crystal could not be imagined, and to the present day remains a sublime mystery. With the departure of Capt. Ross from that terra incognita of the South Polar Sea, more than half a century ago, its darkness and desolation became a memory only, although an expedition under Borchegevink left in 1898 to attempt the solution of the mystery.

In Asia vast progress has been made during the Century in laying down with approximate accuracy the great features of that stupendous continent. India has been accurately surveyed, the task beginning in 1800 and ending in 1883. The Himalayas and other features of Central Asia are now portrayed on maps with almost absolute accuracy as regards general outlines. Mt. Everest and other lofty peaks have been measured, and the forbidden land of Thibet has been invaded by a number of daring travelers, the last and most intrepid of whom are A. H. Savage Landor and Dr. Sven Hedin. Much of our present knowledge of Persia is due to the daring of W. Moorcroft and G. Trebeck in 1819-25, and of Alexander Burnes in 1836-38. In 1838 Lieutenant Wood, of the Indian Navy, discovered Lake Sirikol, supposed to be the source of the Oxus. The valley of the Ganges was traversed in 1847-50 by Sir Joseph Hooker. In 1848 Eastern Turkestan was entered by R. B. Shaw, who collected material for a general map of that unknown country. In 1885 Chinese Turkestan and northern Thibet were explored by A. D. Carey. The coasts of China and Tartary were investigated and accurately surveyed for the first time by the English admiral, Colliston, during the fifties, and in 1862 Captain Blakiston surveyed the Yang-tse-Kiang for a distance of 900 miles. In 1876-1880 extensive

studies of the geography of China were made by E. C. Baber, and in 1881 A. R. Colquhoun made a long and perilous journey across Southern China. Mrs. Isabella Bird Bishop's journey through the interior of Japan, in 1879, was a noteworthy feat, and contributed a vast amount of knowledge regarding a country about which very little had been known. In 1882 Korea was extensively explored by Mr. Carles, the British consul. Prior to 1853 there was practically nothing known of Arabia. In that year Richard Burton, the African explorer, made an audacious visit to Mecca and Medinah. The journey was made at the risk of his life and resulted in an extensive knowledge of the geography of the country and much information regarding the sacred cities of the Mohammedans and the pilgrims who flocked thereto.

The most daring feat of exploration on the North American continent recorded in the present Century is the expedition headed by Captain Meriwether Lewis and Captain William Clarke, which was sent out by President Jefferson in the summer of 1803 for the purpose of exploring the country lying between the Missouri River and the Pacific Ocean. This vast stretch of territory was then in absolute possession of the Indians, and no travelers ever set out upon a more dangerous journey. In the spring of 1804 they began the ascent of the Missouri River, having passed the previous winter on the banks at its confluence with the Mississippi. They could travel only by slow stages, owing to frequent surprises from the Indians, who showed themselves extremely hostile to the encroachments of the whites. The second winter was passed in the Mandans, and not until the middle of June did they reach the great falls. A short distance above this point they discovered the three concurring streams, which they named Jefferson, Madison and Gallatin, in honor of the

President, Secretary of State and Secretary of the Treasury. They ascended the Jefferson to its source, and accompanied by a guide from the Shoshone tribe of Indians, they traveled through the fastness of the mountains until September 22, when they entered the plains of the great western slope. On October 7 they embarked in canoes on the Kooskoosky, which proved to be a branch of the Columbia River, and by November 15, after many thrilling escapes from death, they met the tide of the great Pacific, having traveled more than four thousand miles from the confluence of the Missouri and the Mississippi. The third winter was passed on the south bank of the Columbia River, the explorers devoting every moment of their time to surveying and investigating the surrounding territory. The homeward journey, with all its dangers, was begun on March 23, 1806, and they reached St. Louis September 23, after an absence of two years and four months. In return for the invaluable services rendered the nation in opening this immense territory, Congress made grants of land to all the members of the expedition. Lewis was made Governor of Missouri, and Clarke was appointed a member of his staff.

Few explorers have begun the careers for which they were destined, under such romantic circumstances as did the "Pathfinder," as John Charles Fremont is commonly called. As a young topographical engineer in 1840 he was engaged in Washington in preparing a report of some minor expeditions which he had made a couple of years before. Here he became engaged to Miss Jessie Benton, the daughter of a Missouri Senator, much against the wishes of her parents. Through the potent influence of Colonel Benton, the unwelcome suitor received peremptory orders to go to the Western frontier and make an examination of the Des Moines River. The commands were

instantly complied with, the young officer returned, and after secretly marrying the young lady, projected a geographical survey of the entire United States from the Missouri River to the Pacific ocean. This gigantic task begun May 2, 1842, was successfully accomplished in the incredibly short time of four months. As soon as his reports had been submitted to Congress he planned another and still more extensive expedition, and in May, 1843, he commenced a journey, the ultimate object of which was to explore and survey the terra incognita lying between the Rocky Mountains and the Pacific ocean. On September 6, after traveling 1,700 miles, Great Salt Lake was seen shimmering in the distance. Up to that time nothing accurate had been known about this great inland sea. The upper tributaries of the Columbia were next accurately surveyed, and the journey extended to Vancouver. Returning by the Southeast route, leading from the Columbia to the Colorado River, he found himself in an unknown region encompassed by lofty mountain peaks. It was now late in November, and death confronted the whole party, forty in all. The beautiful summer land of California lay beyond the rugged, snow clad mountain chains, but the Indians declared that no man could cross. Exorbitant rewards were offered, but none were great enough to induce an Indian to attempt to guide the party. At this juncture Fremont won his famous sobriquet of the "Pathfinder." He led his company out and began one of the most thrilling feats in history. Without a guide he crossed the terrible barriers that stood between life and death, and in forty days from beginning the ascent the party was at Sutter's Fort on the Sacramento. When his half perishing men had been restored sufficiently the homeward journey was made. The Sierra Nevadas were crossed, Salt Lake revisited, and in July, 1844, Kansas was entered from the

South Pass. In the spring of 1845 the "Pathfinder" set out with a third expedition to explore the great basin of the Rocky Mountains and the coast of Oregon and California. The skirmishing preliminary to the breaking out of the Mexican war prompted him to now defend the territory he had discovered and explored, and under his leadership in less than a month all northern California was freed from Mexican authority. On July 4, 1846, he was elected Governor of California. During the progress of the Mexican war, he got into difficulties with his superior military officers, was ordered to Washington, court-martialed, and relieved of his command. Undaunted and undiscouraged, he started out on a fourth expedition across the Continent in October. This time the route was along the Rio Grande, through the then unknown country of the fierce Apaches, Comanches, and Utes. Of all his expeditions this was the only unfortunate one. His guide lost his way, and they were stranded far in the Sierra Nevada Mountains in dead of winter. One by one the horses and mules began to die and finally the men. Their sufferings were horrible, and finally cannibalism was resorted to. Fremont, with a remnant of emaciated and half delerious men, succeeded in finding their way back to Sante Fe. No sooner had he recovered from the effects of his terrible experiences than he started out again with a party of thirty, who succeeded in reaching California in the spring of 1849 without serious difficulty.

The most important work in South America was done by the great German naturalist, Alexander von Humboldt, who, having left Corunna under the patronage of the Spanish government, went to Cumana and Caracas; thence in February, 1800, he began his great exploration of the Orinoco. Sailing for fifty-four days up the Magdelena he reached Bogota and in September he began his journey

southward through a vast country that had been practically unknown. He reached Quito, January 6, 1802, and spent the first half of the year in studying the peculiarities of the equatorial Republic, and in scaling and measuring its lofty mountain peaks. The Peruvian Andes were traversed the Chimborazo was scaled to an altitude of 19,286 feet. He followed the Orinoco from its mouth to its source and made a wonderfully accurate map of the river and surrounding country and established the existence of a communication between the water systems of the Orinoco and Amazon, determining the exact position of the bifurcation. Aside from the geographical results of this expedition it was of importance in furnishing him materials upon which he deduced great principles for the organization of the sciences of meteorology and physical geography. The geological and botannical results were of almost equal importance, and these, with the observations made during his Asiatic exploration and other voyages were the basis of his famous work, the Cosmos.

In 1825 Pentland, a British consul, began a series of explorations which led him through the greater part of Peru, Chili, and Bolivia. Like his predecessor, Humboldt, he paid especial attention to the topography of the Andes, measuring their summits and discovering numerous passes. The coast survey from the La Plata to Cape Horn and around to Guayaquil was undertaken and accomplished in 1826-36 by King and Fitzroy, accompanied a portion of the time by the young naturalist, Charles Darwin. In 1835-44 British Guiana was explored by R. H. Schomburgk, the botanist. The rivers of the country were traced to their sources for the first time, and the great basins of the Amazon and Orinoco explored and mapped out. In 1872 Patagonia was traversed by Commander Musters for a distance of 960 miles of latitude, most of

which had never been trodden before by European feet. The region of the Magellan Straits was explored in 1876 by the Challenger force, who landed also in Terre del Fuego. An adequate idea can be obtained of the vastness of the research that has been brought to bear in South American territory, when one looks at a map of that Continent fifty years ago. Not a single pass over the Andes was shown for a distance of 500 miles between Chili and Argentina, while to-day there are a hundred between a latitude of 22 degrees and 35 degrees.

The exploration of Australia has been a strictly English enterprise. The exploration of the interior was begun immediately after the founding of the convict settlement in Botany Bay in 1815. The first important expedition was that led by Edward John Eyre in 1841 from Adelaide to King George's Sound, 1,040 miles distant. The Darling and Murray Rivers were explored by Captain Stuart in 1844-45, and he succeeded in reaching a point within a short distance of the interior of the Continent. After this development was rapid. Augustus Gregory in 1856 ascended the Victoria River to its source, made a long and painful journey to the Gulf of Carpentaria and arrived at Brisbane, having marched a distance of 6,500 miles through absolutely new territory. Queensland was explored in 1843-6 by Leichardt, and in 1857-60 the great lakes and mountain ranges of West Australia were explored by Warburton, McDouall, Stuart, Swindon, and a host of others. South Australia received a careful survey and exploration at the hands of the McKinley expedition of 1861-2. From 1875 until the present time expeditions have been constantly in the field, opening new territory and discovering lakes and rivers theretofore unknown.

EDUCATION

In no direction has there been greater progress during the past Century than in education. The old-fashioned school, in which the sons of the well-to-do were taught as little learning as possible by badly educated masters, usually of the type of Squeers, is a thing of the past. And the greatest reform has been in the direction of the popularization of education. Before the beginning of the Century the children of the poor were for the most part barred from attending even such schools as there were. Charity schools of various types existed, but the state did not seem to realize that one of its greatest duties was to promote the intelligence of its citizens. With the extension of the free-school system there has been a great change in methods of teaching. College education has been improved, schools for instruction in agriculture industrial arts and the sciences have been established. The blind, and the deaf and dumb have been educated, and women have been given an opportunity to acquire as much knowledge as may be possessed by their brothers. These changes have been so gradual that their character and effect has almost escaped popular notice.

"The Nineteenth Century," says Lavasseur, "is the first which has systematized and generalized the education of the people for the value of education in itself." It is true that laws had been promulgated before the year 1800 regarding public education, but these laws, generally speaking, were inoperative, and if some nations were more advanced than others, it is still a fact that at the opening

PESTALOZZI AMONG THE POOR CHILDREN

Painting by Konrad Grab

of the Century a vast majority of the people of the civilized world could neither read nor write.

One of the reasons for the growth of popular education has been the spread of democratic ideas and of the application of industry to science. It began to dawn upon the people how profitable it would be for each inhabitant of a country to be able to communicate with or receive communications from others through ability to read and write. This ability once gained and used, would break down the barriers which cut off a large part of the people from the influence of the current of the intellectual life of the Nation, and also in a measure would efface the inequality which is caused by the neglect to provide any kind of instruction for the masses. There were charity schools supported by the churches or other charitable organizations before the beginning of the Century, but these were few and far between. Whatever education was given was granted as a boon. To-day education is regarded as a right in a civilized country, and an enlightened government appreciates the fact that the illiterate cannot become good citizens. Mental development leads to moral development and influences physical improvement.

Since 1801 the government of every civilized country has either enacted a law or taken measures for the general introduction of public education. In this work, if the United States has not always led, it has made the most progress, until, in 1897, there were 14,652,492 children enrolled in the common schools of the United States. Yet during the period between the revolution and in the early years of the Century the schools of the United States were poor and the number of people who could read or write was small. The constitution of Pennsylvania of 1790 provided that schools should be established "in such a manner that the poor may be taught gratis," but for twenty-six

years the provision was disregarded and the money for education spent upon academies for the classes rather than elementary schools for the masses. Until as late as 1829 indigent parents had to publicly confess their poverty in order to secure free education for their children. The first state to establish a common school fund was Connecticut, in 1795, New York following in 1805, and Massachusetts in 1834. The growth of the idea of public education was slow and in some of the Southern states, free school systems supported by the state did not exist until after the war of secession. When once the benefits of free education became apparent the idea spread. Now the little red school house is omnipresent, although the report of the superintendent of census in 1890 said that as late as 1840 "Massachusetts was most singly conspicuous in the general maintenance of free schools." To-day in all the states education is gratuitous in primary and grammar schools and in some, although not all, in high schools, while there are free universities in many of the states. Indeed there is nothing in the United States so free as education. In 1867 the Department of Education, afterwards made a bureau of the Department of the Interior, was formed. While the National Government has no control over the matter of education, enormous aid has been given by the great land grants for educational purposes in the Western states.

Compulsory attendance at schools dates from 1802 in Bavaria, and, difficult as it is to justly award credit for the first general system of free schools, it would seem that Bavaria is entitled to it. Laws regarding public instruction were enacted by Holland as early as 1801, and the ordinance of 1819 in Prussia made attendance compulsory, while other German states adopted the same idea at about that time. Free school systems were created in the Swiss

cantons between 1830 and 1848; Sweden's organic education law was promulgated in 1842 and Norway gave effect to a similar law in 1848. During the first half of the Nineteenth Century there were school laws in some of the Italian states, and under Louis Phillippe free schools were introduced in France.

While church schools had existed in England the progress of popular education was slow. Grants had been given to schools since 1833, but the commission under the Duke of Newcastle reported in 1861 that the existing system reached but one-eighth part of the population, and the attendance of even this number was irregular, and that even in the best schools not more than one-fourth of the scholars were successfully educated. To this investigation was due the elementary education act of 1870, by which for the first time the English Government assumed the responsibility of securing adequate accommodation in public schools for all children of school age in England and Wales. The territory was divided into school board districts, provision made for the election of boards and the local taxes made contributory to the work. Through the operations of this act in six years the school attendance was doubled. The present English system includes two distinct classes of schools, board and voluntary, the former established by boards elected by the tax-payers, and the latter chiefly church schools, but including also a small number of private undenominational schools. The increase in the number of children in attendance at the schools of Great Britain has been from 884,234 in 1860 to 5,015,845 in 1896.

Some of the British colonies were in advance of the mother country in the matter of education: for instance, the fundamental law of public instruction in Quebec went into effect in 1841, and in Ontario in the same year. Col-

onies under European control, such as Algeria, Australasia, and India have given children the benefits of free education by the state. During the second half of the present Century almost all the Spanish-American Republics established school systems modelled partly on that of the United States. With the growth of occidental ideas in Japan, came the public school system, established by the Mikado in 1872.

It is not alone that education has been made free throughout the civilized world—and wherever civilization is greatest there can be found the greatest educational advantages—but there has been a marked improvement in the methods of instruction. Time was not long ago when the teacher, as a rule, were grossly ignorant. As late as 1820 the most rudimentary knowledge of arithmetic, together with reading, was all that was taught in the free schools of the United States, while writing was taught to but few. At that time the goose quill was the only implement known to the writing master, and he spent a large proportion of his time in preparing the pens for the use of his pupils. A few of these schoolmasters were men of great scholarship for their day, but the average pedagogue was a ponderous creature austere, dogmatic, terrible in his wrath, and depending chiefly upon the rod, not only for his authority, but for his success in imparting instruction. The covenant made between Johanness von Eckklen and the town of Flatbush, Long Island, may stand as sample of the duties required of a schoolmaster in colonial times. In addition to his regular duties in school he agreed to be chorister of the church, keep the church clean, dig graves, and toll the bell. These teachers used the birch often to cover their own deficiencies, and the disappearance of flogging from the schools has come with the improvement in pedagogy. The first normal school

in the United States was founded at Lexington, Mass., in 1839; since then the number of public normal schools supported by the state or municipal governments has increased to 140, with nearly 35,000 students, and there are also private normal schools with 11,000 students. These schools have trained the teachers to make the best of their opportunities for the education of the young, and nowadays the important duty of teaching is not left to men who can do nothing else, as was the case not much longer than a half Century ago. These normal trained teachers have brought the best methods to their aid in their work. The methods are so numerous that we cannot go into detail here. The comfortable, well lighted schoolroom of to-day and the excellent school-books are among the results. It is difficult to make easily appreciable comparisons in a few words, but it may be said that the schools are more carefully graded, fewer pupils assigned to each teacher, much oral instruction, scientific study, and physical exercise introduced, so that while the school year has been shortened, holidays multiplied, and the hours of school attendance lessened, yet in the short school year of to-day more than double the ground is covered that was covered in the long school year of the olden time.

A late development of the Century is the kindergarten, although it had its germ at the beginning of the Century, and it has done much to revolutionize the old way of learning by rote. Johann Heinrich Pestalozzi's ideas are to-day the foundation of all the Nineteenth Century theory of juvenile education. Pestalozzi was a quixotic Swiss, who burned with desires to benefit humanity, and believed that it could best be done by education. Illiterate, ill-dressed, a bad speaker, he was utterly unfit for the every-day business of life, and all his undertakings resulted in practical failure. But he awoke men to a sense of re-

sponsibility to childhood, aroused the admiration of the world by his ideas, and his principles are being carried out to-day, even though it is only within the last few decades that they have met with universal acceptance. Early in the Century Pestalozzi published his book, "How Gertrude Educates Her Children." It is the recognized exposition of the Pestalozzian method and sets forth that the development of human nature should be in dependence upon natural laws with which it is the business of every good education to comply; in order to establish a good teaching method it is necessary to learn first to understand nature, its general processes in man, and its particular processes in each individual, observation, the result of which is a spontaneous perception of things is the method by which all objects of knowledge are brought home to us. This last idea contains the germ of the kindergarten system. Pestalozzi endeavored to put his theories into practice in his own day and labored to educate the ragged children of the poor. To-day those theories have gained almost universal acceptance. They have influenced the whole system of pedagogics and, developed by Froebel, they form the corner stone of the kindergarten system. The progress of the system was slow. The Ronges established the first kindergarten in Germany in 1849 and in England in 1851. In 1870 there were only five kindergartens in the United States, but since then they have become a part of the school system of most of the cities, and in 1897 there were 1,157. Even in Japan kindergartens now exist. As to the benefits of the kindergarten training, the strongest evidence is that out of 10,000 children of the toiling classes who received kindergarten education in one of the largest cities many years ago, only one has been arrested and he was discharged.

Higher education was more greatly developed at the

beginning of the Century than was primary education. While high schools were lacking there were academies in the civilized countries and many of the colleges are centuries old. But there has been a great improvement in college education. The standard for admission has been gradually raised and the course is more thorough. The student in the college is able to receive the results of the ripest scholarship of the world, from men who have aided in its progress and thus new generations of scientists and thinkers are being constantly trained to aid in the development of mankind. The improvements cannot here be traced in detail, but in the United States, which will do as a type of those of the world, there has been an increasing freedom in elective studies enabling the student to follow his bent and specialize his studies, laboratory methods of instruction, lecture instruction, researches in and a growing conviction that the university is primarily a place for instruction and not for the formation of moral or religious character.

The growth in the number of colleges and universities in the United States has been phenomenal. There were about thirty in the United States in 1801, and they probably did not have more than three thousand students, who studied for the most part such courses as are now pursued at academies. In 1897 there were 472, with 155,091 enrolled students in all their departments. Not only have the number of colleges enormously increased, but the magnificent endowments and public grants have placed funds at their disposal which have vastly increased their usefulness.

A feature of the universities has been what is known as university extension. The purpose of the movement, which was originated by the University of Cambridge, England, in 1872, is to extend the advantages of university

instruction by lectures and classes to those who are engaged in the regular occupations of life. Its success in England led the University of Pennsylvania to institute a similar plan in the United States at Philadelphia, and its success in Philadelphia led to its gradual dissemination throughout the country.

Another development of the Century has been the establishment of agricultural, commercial, scientific, and industrial schools. The first agricultural school was that established by Count Fellenberg at Hofwyl in Switzerland in 1799. The idea then sown has borne fruit, until now agricultural schools exist in all of the civilized nations.

Germany and Switzerland led in the establishment of technical schools, which owed their origin to the endeavor to train men to compete with those trained in British workshops. Little technical training could be had in a university in those days, although scientific schools are a part of nearly every such institution. Among the earliest developments of the Century are the polytechnic schools at Zurich, Munich, Vienna, Stuttgart, Hanover, Dresden, Berlin, and Moscow. The first of them all was the Ecole Polytechnique of Paris, but that was intended primarily to train men for the artillery and engineering corps of the French army.

Civil engineers had to go abroad to study before the Rennselaer Polytechnic Institute was established at Troy, N. Y., in 1824, with no dead or foreign language in its curriculum. In 1826, twenty-five students were registered, while now more than 20,000 are attending the courses. The Sheffield Scientific School of Yale University was established in 1847, the Lawrence Scientific School of Harvard in 1848, and the Chandler Scientific School of Dartmouth in 1852. The land grants of 1862 by Congress encouraged this system of education and

scientific courses were added to the state universities, while Columbia organized its School of Mines, Washington University of St. Louis its School of Engineering, and in 1861 the Massachusetts Institute of Technology opened its doors. In 1871 the Stevens Institute of Technology was founded at Hoboken, and the Green School of Science was established as a branch of Princeton College. The growth from that day has been steady until now, in practical scientific education, the United States ranks with the best in the world.

Trade schools, designed to develope trained craftsmen, are new, and in these Germany and Switzerland also led. In Germany there are now schools to teach every trade; there are building schools, weaving schools, metal working schools, schools for designers, wood-carvers, molders, founders, turners, pressers, engravers, etchers, gilders, etc., etc. The industrial arts have been developed to achieve wonderful results. France, Austria, Belgium, and Holland have also excellent industrial schools. In Great Britain the first school of design was opened at Somerset House in 1837, and since then many scientific and technical schools for industrial education have been established. Trade schools in the United States began with the New York trade schools, founded by Robert T. Auchmutty in 1881, which were commenced simply as night schools. Since then about a dozen similar schools like the Pratt Institute in Brooklyn, the Textile School, and the Drexel Institute in Philadelphia, and the Armour Institute in Chicago, have been established, while many of the scientific schools supply to some degree the desire for a technical training for those who wish to gain knowledge for application in trades.

Commercial education by the state has not been developed to as great extent in the United States as in Ger-

many and elsewhere on the European Continent. Yet many good business schools have been established in the larger cities where young men and women are taught the rudiments of commercial education.

Manual training in the schools owes its introduction largely to the success of the ideas of Froebel. The laboratory method of instruction was first applied to the mechanic arts in the Imperial Technical School at Moscow under its director, Victor della Vos, in 1868. But manual training or slojd, as we know it to-day, was first completely worked out in Sweden, commencing in 1876. There are now over 700 schools where slojd is taught, and from Sweden the idea has gone to all countries. Woodwork is taught the boys and needle-work and cooking to the girls. The first instruction of sewing in free schools was given in those of France in 1867.

In the United States manual training is now not only taught in the industrial schools, but children in the grammar grades of the larger cities are given lessons. They make little things that they are allowed to take home. The idea is not to fit them for a trade, but to train the hand as well as the brain, and the work is small work, without any division of labor, as there would be in the actual prosecution of the trades for pecuniary profit.

Professional schools are also a development of the Century. There was no school for the training of the physician or surgeon in the early days of the Century, and the lawyer read law in an office. The increase of knowledge has made greater application necessary for its mastery, and this has made the professional schools indispensable.

In no direction has there been greater progress than in that of the education of women. The report of the English Royal Commission of 1864 declared that the best edu-

cation for the female mind was then believed to be steady application to vocal and instrumental music and to the subject of ladylike manners and deportment. Instead of gymnastics or games, instruments of torture for modeling the figure were used. In 1849 Bedford College was founded in England chiefly through the influence of Mrs. Reid. Women were not admitted to university examinations in England until 1867, when the doors of the University of London were thrown open and, in 1871, Miss Clouch opened a house for women students in Cambridge, which in 1875 became Newnham College. Women were formally admitted to Cambridge in 1881 and somewhat similar privileges were given at Oxford in 1884. The two earliest women's colleges in the United States are generally reported to be Mount Holyoke, which dates from 1836, and was organized by Mary Lynn, but it had for its curriculum merely an academic course, and this is true of the Georgia Female College, opened at Macon, Ga., in 1839. The first institution in the world designed to give women a full collegiate course was founded at Poughkeepsie, N. Y., in 1861 by Matthew Vassar and it was opened in 1865. The first co-educational institutions were Antioch and Oberlin Colleges, but during the last generation co-education has met with growing favor, until now more than half the colleges of the United States admit women as well as men. Having gained a collegiate education the women sought admission to the professional schools, which they have gradually secured, until now women lawyers and physicians are quite common in the larger cities. The growth of the higher education of women abroad has been slower, but gradually the idea is extending, until within another generation women everywhere are likely to have the same educational advantages as men.

The Nineteenth Century educator has turned his attention to the education of the defective classes, the blind and the deaf and dumb. Remarkable progress has been made in this direction. Systematic attempts to educate the deaf and dumb has been made as early as 1570 by Pedro de Ponce, a Benedictine monk, yet little headway was made until near the close of the Eighteenth Century, when the schools at Paris and Edinburgh were opened. The first institution for the education of the deaf and dumb in America was opened under Dr. T. H. Gallaudet at Hartford, Conn., April 15, 1817. A church for the deaf and dumb was opened in London in 1870, and in 1876 Rev. Henry W. Syle, the first deaf and dumb person to be ordained to the ministry, was given orders in the Episcopal Church at Philadelphia. The adoption of what is known as the visible speech method, by which the deaf are taught to read the words of speakers by the movements of the lips, owes its suggestion to Alexander Melville Bell, who explained his ideas before the London Society of Arts, March 14, 1866.

The first public school for the blind was established at Paris in 1784 by Valentine Hauy, and he began printing for the blind in raised characters in 1786. The whole Bible in raised characters was first printed in 1848 at Glasgow. Education for the blind has so developed that the sightless may be taught to do many things that seem almost incredible. Not only can they study almost anything that other human beings do, but they are able to play tag and shinny with all the energy of youth. Books for them are not now printed in characters like those used by those who can see. By the Braille system, which now is used almost universally, arbitrary characters are employed which are more readily detected by the fingers than are the Roman characters. Instruction is given by utiliz-

ing the sense of touch to the utmost, and this has been capable of some almost miraculous developments. The most remarkable known case of the education of the blind, deaf, and dumb is that of Helen Keller, whose story seems almost incredible. Miss Keller, blind and deaf, having never heard human language, has learned to speak and write French and German as well as a native of France or Germany. Her English, too, is perfection. She has read all the great authors, can recite Shakespeare, Goethe, and Hugo, writes good poetry herself and knows a good deal of Greek and Latin. To accomplish this marvelous result years of infinite toil and patience were spent by her and her interpreter and friend, Miss Sullivan, who, before undertaking the instruction of Helen, was a pupil teacher in a deaf-mute institution. The teacher began by establishing a sort of telegraph code between herself and her pupil in the form of finger taps on the palm of the little girl. Helen learned to give utterance to language by placing her fingers on Miss Sullivan's lips, face and throat, and then imitating the motions made by her teacher with the same muscles. She rides a bicycle and is going to Radcliffe College, the annex of Harvard, the preliminary entrance examinations for which she has already taken.

MEDICAL SCIENCE, HYGIENE, AND SURGERY

To the sick and suffering science has proved, in the Nineteenth Century, an angel with healing in its wings. The healing art, in all its branches, has made more progress during the last hundred years than it had made in all the history of the world.

The Egyptians were possessed of many of the secrets of medicine as long ago, or longer, than 4000 B.C. From them the Israelites learned the principles of their medical practice and with the Israelites, as with the Egyptians, the priesthood prescribed for the sick. In India, in the Eleventh Century B.C., the healing art appears to have been better understood than it was by either the Egyptians or the Israelites, but it was still empirical. Greece was the birth-place of rational medicine, which traveled, by way of Alexandria, to Rome. After the fall of Rome, the Arabians, those true disciples of science, kept alive the torch of medicine. Expert chemists, they made an especial study of pharmacy and of drugs, founding apothecaries' shops and the pharmacopœia. During the dark ages the Jews and the Mohammedans were the skillful physicians. The Jews retained many of the sanitary and hygienic ideas of the Pentateuch at a time when such ideas were sorely needed. Latin translations of Arabian renderings of Greek works on medicine helped Europe to recover its knowledge of the medical lore of antiquity. The study of anatomy, of physiology, and of medical botany began and very gradually the foundations of true medical science were laid. Ambrose Paré, who died in 1590, is called the father of modern surgery. In 1628

William Harvey explained the circulation of the blood, with the effect of setting many ingenious minds to work at trying to place medicine on a physiological basis. The Eighteenth Century was mainly spent in efforts to construct a theoretical system of medicine, but the acquisition of positive knowledge did not stop.

Yet at the beginning of the Nineteenth Century medical science and its practice were in a state difficult to realize in this day of education and enlightenment. The most learned physician was a babe in knowledge compared with his brethren of to-day. In England medical practitioners were divided into three classes, physicians, surgeons, and apothecaries, most of whom had some knowledge of their profession, although libraries were few and medicine generally in its infancy. Still they had received a technical education and had been examined before admission to practice. But beneath these was a host of empirics who practiced without diplomas—surgeons, apothecaries, cuppers, leechers, herb-doctors, who were most harmless of all, men-midwives, and dispensers of drugs. It was because of these charlatans that the first advance toward improvement was made. It came from the doctors who were actuated by motives both selfish and altruistic. Some earnestly desired to benefit mankind, others objected to their un-diplomaed competitors only because they interfered with their practice. Both classes of reformers, however, worked to the same good end. The Society of Apothecaries took precedence of both the College of Physicians and the University of Surgeons, in the good work, and it was through its efforts that the Apothecaries' Act was passed in Parliament January 15, 1815. This declared it necessary that every medical man should give evidence that he possessed some knowledge of his profession before he began to practice, and that all apothecaries

should be licensed. The act was enforced with much wisdom, and so began a revolution in medicine.

Anatomy soon showed the effect of the new state of affairs, for a thorough knowledge of the human body was insisted upon as a qualification for the practice of medicine. But the obtaining of subjects for dissection was attended with great difficulties. Bodies had to be imported from abroad and body-snatching, dangerous as it was, was often the only means by which subjects could be procured. In the United States, where only skeletons could be brought from abroad, this was still more the case, and when the medical school was opened at Harvard College a single body did duty for a year's lectures in anatomical demonstration. Students were forced to learn from books without the aid of practical demonstration and doctors gained knowledge through mistakes, killing not a few patients in the course of their experiments. People were bled for fevers and for fainting fits; ten grains of calomel was a usual dose for an adult, and cases of salivation, with the loss of teeth were of common occurrence. Still the old country doctor, whose saddle-bags were the only drug store within twenty miles, who was every one's friend and who, for a radius of ten miles or more, ushered all the babies into the world and closed the eyes of the dead, was a power in the land, who ranked next to the justice of the peace, if he was not himself one, and to the minister. He did his best for all his patients, and thought far more of their good than of his fee, often riding ten miles for less than the physician of to-day asks to step next door. With tears in his eyes, he refused cold water to his fevered patients, and denied fresh air to weak lungs, from the kindest of mistaken motives.

Most of the remedies in his saddle-bags are unknown to the present generation, and he had few or none of the

weapons with which the medical men of to-day fight disease and death. Laudanum was the best sedative in his pharmacopœia, while prior to 1820, he knew quinine only in its original form as Jesuit's or chinchona bark, which, administered in powder, called for such large doses, and was so costly as to be practically useless to the masses. Anaesthetics were unknown until 1846, when sulphuric ether first was used, and there were no antiseptic bandages and no surgical cotton. Well people took huge doses of sulphur and molasses and of jalap, in the spring, to clear their blood. As a rule, it was believed that the efficacy of a drug was in exact proportion to its nauseousness, and no one had faith in small doses.

A college course in the early part of the Nineteenth Century was expensive and not obligatory. To have "read with a doctor" was all that the law required for the granting of a license to practice medicine. In a doctor's office there were usually one or more students whom he taught what he knew, to the best of his ability; what they learned depended on their own. There were comparatively good medical colleges in Paris and in Vienna in which clinical surgery and medicine were taught. The intellectual awakening resulting from the French Revolution gave an impetus to reform in France, in which medicine participated. Marie Francois Xavier Bichat, who died in 1802 when only thirty-three years of age, in his short life-time, through his "Anatomie generale," supplied a new basis for the science of disease. He was followed by Broussais and Bouillard, who tried to find an anatomical basis for all disease. Broussais is noted for his explanation and treatment of fevers, which led to a great misuse of bleeding. It is recorded that he used 100,000 leeches in his own hospital wards in one year.

Avenbrugger, of Vienna, invented direct percussion in

the Eighteenth Century. Mediate percussion was introduced by Piorry in 1828. Supplemented by auscultation, it revolutionized the methods of medicine, making possible exact diagnosis. Auscultation is accomplished by means of the stethoscope. By its use it is practicable to determine the condition of heart and lungs by listening to the sounds produced by their movements. This valuable instrument was in general use abroad long before the average English or American practitioner availed himself of it.

The discovery of anaesthesia conveyed a priceless boon to mankind. Chloroform was discovered in the early thirties by Gruthrie in America, Liebig in Germany, and Soubeiran in France, but not until 1847 was it used as an anaesthetic. In 1839 the surgeon Velpeau wrote:

"The escape from pain in surgical operations is a chimera which it is idle to follow up to-day. 'Knife' and 'pain' in surgery are two words which are always inseparable in the minds of patients, and this necessary association must be conceded."

Yet, during the next few years, various discoveries revolutionized the practice of surgery and banished the intense agony caused by the knife. In 1844 Horace Wells, a Massachusetts dentist, inhaled nitrous oxide and, while he was under its effects, a brother dentist painlessly extracted a tooth. In 1846 William Thomas Green Morton, another dentist, made use of ether as an anaesthetic. It has been claimed that he was not the discoverer of the anaesthetic properties of sulphuric ether, and that Dr. Charles Thomas Jackson revealed to him the secret. However this may be, William T. G. Morton obtained permission from Dr. John Collins Warren to etherize a patient on whom the physician was going to operate. This was done in 1846 at the Massachusetts General Hospital. From Boston the use of ether in connection with surgery

spread to all parts of the world. In 1847 Dr. James Young Simpson, of Edinburgh, inaugurated the use of chloroform as an anaesthetic. We are told that, while yet a boy studying medicine, Simpson was so overcome by the sight of the sufferings of a woman undergoing a surgical operation, that he resolved to abandon the profession, feeling that he could never learn to endure such sights. But, happily, he altered his decision, determining rather to devote himself to finding something to alleviate or banish the pain of those under the knife.

In those days it was a matter of pride with the surgeon to use the knife quickly and dexterously, so as to perform an operation with the infliction of as little pain as possible. Sir Robert Liston won a brilliant reputation throughout Europe for the extraordinary rapidity with which he could perform the most difficult surgical feats of the day. It is said that he could amputate a thigh in less than a minute. Liston died at the height of his fame in the year that Simpson introduced chloroform as an anaesthetic. It is pleasing to know that he had the extreme pleasure of using anaesthesia before he died. Operations in the days before patients could be "put to sleep" were torture to the surgeon as well as to the patient. In December, 1846, the great surgeon administered ether for the first time in the theater of the University College Hospital. When the operation was finished, according to an eye-witness of the scene, "everybody seemed pale and silent except Liston, who was flushed and so breathless that when he broke the silence with the word, 'Gentlemen,' he almost choked."

Simpson did not consider ether an ideal anaesthetic and continued his experiments after the use of it. He finally found what he wished in chloroform, which he held was particularly adapted to his own department of practice, midwifery. A relative of Simpson's family, Miss Grind-

lay, tells a dramatic story of his announcement of his discovery. She says that one day he came quickly into the dining-room and, taking a glass from the sideboard and a tiny phial from his pocket, poured a few drops from the phial into the glass, saying, "See, this will turn the world upside down." Then, inhaling the liquid, he fell down unconscious, greatly frightening the family.

Many objections were opposed to the use of anaesthetics. Among others it was seriously argued that as pain was part of the curse of Adam and Eve it was wicked to abolish it. Simpson was ready with an answer to this extraordinary objection. He showed how God himself, when he performed the first surgical operation—that of taking a rib from Adam's side, in order to make woman—caused the man to fall into a deep sleep.

Ether is preferred as an anaesthetic in America, and chloroform is the favorite in Europe. Through their use wonders have been wrought. Not only are the pain of patients minimized and the evil effects of its dread banished, but the operator is no longer obliged to hasten his work unduly. He is enabled, unhindered by the sufferings and struggles of those under the knife, to proceed slowly and cautiously, with minute attention to detail. All this renders possible operations which could not have been performed in the old days and in the old ways.

Just here antiseptics step in and immeasurably increase the scope and lessen the danger of surgery. Blood-poisoning and other terrible results used to follow almost unfailingly certain sorts of wounds. Simple fractures in which the skin was unbroken used to heal easily and well, but, if there were even a slight break of the skin, the wound would fester and cause great trouble. Amputations were considered necessary in numerous cases which the surgeon of to-day finds simple. Such amputations were followed

apallingly often by gangrene or other putrefactive processes. Louis Pasteur led the way in discovering that germs or microbes from the air caused the festering and poisoning of wounds. In 1867 Joseph Lister first published his experiments on the antiseptic treatment of wounds. He thoroughly appreciated the work of Pasteur and, applying his theory to the process of healing, recognized that living organisms must be excluded from wounds. On this basis he founded a system of antiseptic surgery which has almost done away with pyæmia, septicæmia, gangrene, and erysipelas, and greatly reduced the mortality in hospitals. Statistics show that in 1861 in the hospitals of Paris, there were three deaths resulting from each five cases of amputation, and the state of affairs in Great Britain, Germany, and Austria was almost as bad. After Lister's introduction of his methods into his hospital wards in Glasgow, the death rate after major amputations fell from 45 to 15 per cent in two years. Later it fell lower still.

In 1881 Professor Koch, of Berlin, announced to the scientific world that perchloride of mercury or corrosive sublimate was a more powerful antiseptic than thymol, eucalyptus oil, iodoform, and boric, salicylic and carbolic acids, which were all in use. This and carbolic acid are now the usual antiseptics. The hands, the clothing, instruments of the operator and his assistants are carefully sterilized before an operation is performed, and the atmosphere is impregnated with an antiseptic. Such treatment is called aseptic and does away with the necessity for disinfecting the wound with chemicals. Armed with antiseptics or the precautions of the newer aseptic methods the surgeon can perform feats which were scarcely imagined half a Century ago.

Diseases of the bones and joints are wonderfully

dealt with. Hip disease, so long thought incurable, is, in its milder forms, completely banished without any evil effects; in its severer aspects a few inches of bone are sacrificed and the patient recovers, possessing, it is true, a shortened limb, but one strong and well. Henry J. Bigelow (1852) was the first surgeon in the United States to perform this operation of excision of the hip joint. "White swelling," or scrofulous, or tuberculous disease of the knee no longer entails the loss of the thigh, instead merely the diseased tissues or articulation is removed. Hideous deformities which used to be entirely irremediable are amenable to the surgeon's skill. Humped backs and lateral curvature of the spine are overcome by enveloping the patient in a jacket formed of crinoline covered with wet plaster of Paris. The subject hangs with both hands from a bar while he is encased in this. The jacket hardens, and is left on; from time to time, it is replaced by another and, at last, the crooked back is straight. Club feet are made symmetrical by the wise use of the knife applied to contracted tissues or misshapen bones. Bow-legs and knock-knees and other deformities of the limbs are straightened by the surgeon's boldly cutting across the crooked bones, putting them in proper position and ensuring their correct growth by encasing the limbs in plaster of Paris and leaving them to the healing of nature. These wonderful benefits are not for the wealthy alone, for there are charitable institutions to which the poor may apply and receive help.

If a fracture of a bone of the arm or leg refuses to unite or mends improperly the surgeon lends his aid and, cutting down to the refractory fragments of bone, drills and joins them with silver wire or lends them the support of a silver splint held in place by tiny screws. The wound is closed,

the broken bone heals, and the silver becomes embedded in the tissues, where it is left.

The United States has led the way in the ligation of the larger blood-vessels. Some of the Americans who have gained distinction by the performance of such feats—each one of which was a triumph of surgery—are Amos Twitchell (1781-1850), first to tie the primitive carotid artery; John Syng Dorsey (1783-1818), first American to tie the external iliac artery; William Gibson (1784-1868), first to tie the common iliac artery; Valentine Mott (1785-1865) tied the arteria inominata; J. Kearmey Rodgers (1793-1857) tied the left subclavian artery between the scaleni in 1846; John Murray Carnochan (1817-1887) ligation of the femoral artery in 1851; Hunter McGuire tied the abdominal aorta in 1868. This had been accomplished, in 1817, by Sir Astley Cooper. Not only are such wonders wrought with blood-vessels and frightful hemorrhages prevented, but cases of internal aneurism which were formerly thought hopeless are now cured.

In dealing with nerves the modern surgeon has none of the dread which forbade the old-time practitioner to touch them. Nerves are spliced and sewed so that evil results from accidents to them are entirely prevented and, for the cure of obstinate neuralgia, surgeons actually penetrate to the root of the disease in spinal column or skull. In 1856 John Murray Carnochan performed the exsection of the superior maxillary nerve beyond the ganglion of Meckel.

Skin-grafting is another performance of the Century. Ulcerated or otherwise diseased surfaces on a patient's body are supplied with healthy cuticle transplanted in small portions from other parts of his own body or from other individuals. Injuries which were pronounced incurable in former days are thus entirely healed. The French

surgeon Reverdin is especially celebrated in connection with skin-grafting on ulcerated surfaces.

The large cavities of the body are all reached by the surgeon's knife. He excels in abdominal operations. He cuts into a kidney or the liver and sews them up again with ease. He can remove one of the kidneys from the body, if necessary, leaving the other to do its work. Or if one of these organs becomes dislocated the surgeon sews it into place. The gall-bladder, the spleen, and the pancreas can each be excised and many inches of the intestine can be cut away. Indeed, in some cases several feet of the intestine have been removed with the successful re-establishment of the alimentary canal. It was William T. Bull who first showed that intestinal wounds can be mended with needle and silk. It is a difficult piece of work and must be accomplished quickly enough to prevent leakage of the contents. Surgical needle-work is so deftly performed that even the suturing of longitudinal wounds of blood-vessels is done. Professor Horoch, of Berlin, has accomplished wonderful feats in the suturing of veins and even arteries. Tumors are removed from the brain, the skull being opened for the purpose, as well as for the stoppage of intracranial bleeding and for the treatment of intracranial abscesses. Lately, surgeons have been trying to cure epilepsy by trephining operations to remove the pressure on the brain, which is thought to be the cause of that disease. The thorax is penetrated for various reasons; sometimes for banishing empymea, and sometimes for operations on the lungs. A wound in the heart has been considered, throughout the ages, absolutely fatal. But Dr. Rehn, of Frankfort-on-the-Main, successfully demonstrated that such is not necessarily the case. He sewed up a cut in the heart occasioned by a knife thrust, and his patient recovered. Thus the very "tripod of life,"

SCIENCE CONSOLING A STRICKEN MOTHER—L. PASTEUR IN HIS LABORATORY

Painting by L. E. Fournier, Ecole Normale Supérieur, Paris

as Bichat called the brain, the heart and the lungs, are the subjects of the surgeon, who over and over saves a life by his daring and skill where death were else the only chance.

The modern surgeon has a valuable ally in electricity, not only in the treatment of disease, but as an aid to diagnosis. The French scientist Trouve was experimenting with fish when he discovered a way of illuminating the interior of their bodies so that their entire internal anatomy was visible. A fish was tempted to swallow a small electric light bulb which could be withdrawn from its stomach at the will of the scientist, who had attached to it a wire. Trouve was delighted with his invention, which enabled him to study the interior organism of his fish, but the glass bulb was put to another use by a physician who saw it applied to the fish. He persuaded a dyspeptic patient to swallow such a lighted bulb, and found that he could, in a darkened room, see what was the matter with his stomach. The cancer in the stomach of the Count of Paris was discovered in this way. The physicians talked of supplying the count with the stomach of a lamb instead of his own diseased organ, but the risk was so great that the idea was abandoned. It is a common thing nowadays to examine the interior of the bladder with an electric light. The throat is inspected, a search-light being thrown into the wind-pipe to find out if there is anything the matter with that organ. Instruments of the greatest delicacy have been made for removing abnormal growths from the throat when they have been revealed by the electric light. To the layman, however, the most striking use of electric light in surgery is the illumination of the body to discover if anything is wrong with the pharnyx or other cavities behind the face. The whole mask of the face is illum-

inated by an electric bulb, and the result is ghastly to the observer.

More wonderful in its results has been the application of the Röentgen Ray to surgical operations. Frederick Strange Kolle, one of the most prominent of the newly arisen specialists in radiography, gives eight uses to which the X-rays can be applied in medicine and surgery. These are: To study normal anatomy; to preserve the relations of fragments in fractures of bones; to study and diagnose its locations; to study and diagnose diseased bone; to diagnose anchylosis of joints; to locate foreign bodies, i. e., bullets, needles, glass, wood, etc., in flesh or bone; it is of diagnostic value in cases of tumors or enlargements of inner organs, such as the spleen, liver, kidney, heart, etc.; in obsetrics radiograms may be used to show the exact relations between the bony pelvis and the fœtus in utero.

The fact that certain forms of disease are caused by low organisms was suspected long ago, and expressions of the theory are found in ancient writings. Nevertheless, the establishment of the germ theory of disease and the science of bacteria is recent. Bacteria were described, in the Seventeenth Century, by Leeuwenhoek, who discovered some forms of them, notwithstanding the imperfection of his microscope; but the study of bacteria made little progress until nearly the middle of the Nineteenth Century. The phenomena of fermentation had attracted the attention of scientists, and there was much discussion of the process and its cause. In 1836 Cagniard-Latour detected and described an organism, the yeast plant, on which depends the process of fermentation. The same discovery was made by Schwann, in 1837, and was confirmed in 1843 by Helmholtz. Louis Pasteur elaborated the doctrine through a long course of painstaking experiments, and many other scientists, notably Schultz, Schroe-

der, Dusch, Lister and Tyndall, added their quota to its establishment. It was shown that fermentation is caused by the presence of such organisms, which grow and multiply in the fermenting fluid. Through the valuable aid of the microscope, other low organisms were also discovered and examined, and it was found that many diseases of plants and animals are caused through such agency. In 1848 Fuchs discovered bacteria in animals which had died of septicæmia, and in 1849 Pollender observed rodlets in the blood of animals sick with anthrax or splenic fever. Soon after, Davaine identified those rodlets as the specific virus of the disease. They are called bacillus anthracis. This was substantial proof of the germ theory. Mainly through the researches of Koch, the life history of various bacteria has been made known. In 1882 the bacillus tuberculosis was discovered by Koch, and asserted to be responsible for consumption. The bacillus of cholera was discovered also by Koch in 1883.

Bacteria pervade the world, and are to be found in all three kingdoms, animal, vegetable and mineral, and wherever the conditions are favorable, they develop and multiply. They are breathed in the human body with the air or are swallowed with every mouthful of food that is taken. If they meet with the proper conditions for their growth and reproduction they may do vast harm. Once in circulation they may be carried to every part of the body and injure its organs. It has recently been discovered that the white corpuscles of the blood are living organisms, which are ever on guard to overcome harmful bacteria. The leucocytes, as these white corpuscles are called, are generated by the spleen. They do their work well as long as the bacteria are not too numerous or malignant for them, which is seldom the case when food is good, air and water are pure, and proper sanitary rules are observed.

Bacteria are sedulously studied by scientists who hope to discover the proper means of preventing disease by germ destruction or by inoculation. Thus in 1894 was discovered the antitoxin cure for diphtheria. In order that such profitable investigation may be carried on, much ingenuity is devoted to the cultivation of bacteria, and many ways of securing complete isolation of each kind of bacterium have been introduced. Not only is it necessary to carefully examine each specimen, which is cleverly accomplished by methods of staining, but the life history of each micro-organism must be carefully watched throughout its stages. The micrococci or sphaerobacteria are the kind of bacteria found most often in connection with disease. The bacterium usually is distinguished by the name of the disease of which it is the exciting cause.

Among the remarkable results of Louis Pasteur's researches is the method of preventing hydrophobia by inoculation. His first experiment was the inoculation of two rabbits with mucus from the mouth of a child who had died of hydrophobia. This was in December, 1880. Nearly five years after, in July, 1885, the first human being was inoculated for the prevention of the dread disease. This was Joseph Meister, an Alsatian child, who had been severely bitten in fourteen places by a mad dog. Eminent Parisian physicians pronounced the boy almost certain to die of hydrophobia. Pasteur treated Joseph with daily injections of a series of spinal cords of rabbits who had been inoculated, beginning with one kept so long that it was too weak to harm even a rabbit, and ending with one virulent enough to give a large dog the rabies in eight days. The successive inoculation lasted thirteen days and prevented the boy's having hydrophobia.

A special feature of the medical science of the present era is its tendency towards specialization. This has given

rise to physicians who devote their entire energies to a chosen branch of their profession. Ophthalmology, or the science of the eye, has been carried to a remarkable state of development. Von Helmholtz, the famous German scientist, has been called the "father of the modern school of ophthalmology." He revolutionized the science by the invention of the ophthalmoscope. This is a disk-shaped mirror with a small hole through the center, and is used for examining the interior of the eyes. The physician seats the patient beneath a lighted lamp, and throws a reflected ray of light into the patient's eye, and perceives the interior of the eye illuminated by the ray of light. He can then see how things are, both inside and outside of the organ, and prescribe accordingly. The eye is more thoroughly understood than any other organ of the body, which is well, for, owing to its complicated structure and extreme delicacy, it is peculiarly liable to disease and injury. Many diseases which were thought incurable until within the last fifty years, are now constantly remedied. Errors of refraction, such as myopia or short-sightedness, and hypermetropia or far-sightedness, were not well understood until Franz Cornelius Donders, professor of physiology at Utrecht, published his work on "Anomalies of Accommodation and Refraction of the Eye." Long before the Christian Era artificial eyes were made of gold, silver, copper and ivory. To-day they are made so ingeniously that it is difficult to detect their presence. The finest ones are made in France, of a superior kind of porcelain, by a secret process. Others are manufactured of glass and come from Germany.

Dentistry is almost entirely a growth of the Nineteenth Century, and a marvelous growth it is. It is claimed that the ancient Egyptians were familiar with some of the methods of modern dentists, but the fact has never been

adequately proved. The Greeks and the Romans understood a few principles of dental science, and were able to relieve pain and to make false teeth. During the Middle Ages and for long afterward, dentistry shared the fate of medicine and surgery, and made almost no advance; in fact, for centuries its estate was far lower than it had been in ancient times. The barber was the dentist as well as the surgeon, after the Church of Rome forbade priests and monks to perform bloody operations. But surgery rose to the dignity of a profession long before dentistry was regarded as a calling which a gentleman could properly follow. Nor is this to be wondered at when the state of its practice is considered. Pulling teeth and plugging them, as the rude filling of the time was fitly called, were its principal operations.

The American dentist has led the way in the perfection of his art, and he is justly celebrated all over the world. The first native dentist in the United States is supposed to have been John Greenwood, who began to practice in 1788. Thirty-two years after there were one hundred followers of his calling in the United States; in 1892 there were 18,000. So important has the science of the teeth grown that from 1800 to 1892 there were published two hundred volumes devoted to that subject alone. The first dental school in the United States was chartered by the Maryland Legislature in 1839. Since then colleges and schools of dentistry have sprung up all over the land. If there are as good dentists in other countries as there are in this it is largely due to the fact that they have been trained in American schools. Men come from all over the civilized world to the United States for higher education in dentistry. American ingenuity has invented numerous mechanical aids to the practice of the art. From 1880 to 1890 over 500 dental instruments were patented

at Washington. In his methods the dentist is well abreast of the times, so that what were considered wonderful labor-saving inventions only a few years ago are being rapidly succeeded by others still more useful and remarkable. The dental engine is now run by electricity instead of by the operator's foot, and the same force has been applied in other ways to assist the practitioner. There is an electric mallet for use in filling excavated cavities, which is both ingenious and useful; there is an electric syringe for drying out cavities, and small electric lamps are used in connection with reflectors for exploring the mouth. Nor is this all; the new power, compressed air, is used to keep the saliva away from the part of the mouth under treatment.

Before the rise of the American dentist, the most advanced practitioners were to be found in France. The first dentist to set foot in this country was Dr. Joseph Lemaire, who landed in July, 1778. One of the triumphs of American dental science is the implanting of human teeth in artificially formed sockets of the jaw. In 1881 Dr. Younger, of San Francisco, made the first artificial socket for a tooth. He discovered that a tooth that has been extracted, even a long time before, may, after being thoroughly prepared and sterilized, be implanted in such a socket and left with confidence that the bony tissues will harden around it, holding it firmly in place. The operation has been repeated successfully many times since it was first performed by Dr. Younger, although the announcement that it could be done was met with ridicule and incredulity.

In connection with the advancement of medical science must be mentioned the fact, already alluded to, that anæsthesia was a discovery of American dentists, notably of Horace Wells, who made the first use of "laughing gas."

It has been estimated that fully one-third of the teeth extracted in civilized countries are removed while the patients are under the influence of anæsthesia.

Hygiene scarcely existed during the Middle Ages. The ancients had regarded simple laws of health and the prevention of disease, but these were neglected or forgotten, together with many other things, for centuries. The Mohammedans and Jews alone practiced sanitary science. The rest of Europe did not realize that the public health might be preserved and disease prevented by cleanliness and the observation of simple rules of health. The cities of Europe were filthy; there was practically no drainage and people herded together so closely that no one can wonder at the frequent occurrence of terrible epidemics. Such visitations were received as inevitable, and they were allowed to run their death-dealing courses, unchecked. Often the bodies of those who had died with the Black Plague were allowed to lie unburied for days. The one measure for warding off infection was the burning of pitch in the open streets "to purify the air." In the Twelfth Century fifteen epidemics are said to have occurred; in the Thirteenth Century there were at least twenty. The condition of the people can scarcely be conceived. In England, even in the time of Elizabeth, many still lived in clay-plastered hovels. The fireplace was often a place hollowed out in the clay floor and there was no chimney, the smoke escaping through a hole in the roof. The floor was strewn with rushes, "under which," to quote Erasmus, "lies unmolested an ancient collection of beer, grease, fragments, bones, and everything nasty." The use of rushes for a floor covering was by no means confined to the occupants of hovels. We are told that the floor of the presence chamber in Greenwich palace was, at this time, covered with hay. Personal cleanliness was as little understood

as the care of the house. Clothing was often worn until ready to drop off with rottenness. The Black Death or Great Pestilence came to Europe from the East. It is estimated that its victims numbered 25,000,000. In 1348 this terrible epidemic visited England, where it raged frightfully, fed by the squalor and filth which it found. Again and again it broke out, until it reached its climax in the Great Plague of London in 1665. Another awful epidemic in London was the "sweating sickness," which usually killed its victim in twenty-four hours or less. Erasmus did not hesitate to attribute this dread disease to the filthy habits and neglected surroundings of the people. The Great Fire was a blessing in disguise. It removed many of the impurities and disease centers of the city, and prepared the way for wider streets, better houses and improved paving.

Street paving was one of the things most neglected in the dark ages. In the Moorish cities of Spain fine pavements still remain, testifying to their high civilization, but until the Twelfth Century, the streets of Paris were unpaved. They were then so filthy that it became absolutely necessary to improve them. Paving was followed by a dim perception of the need of some system of drainage, but its evolution was slow indeed. Jail fever was one of the diseases resulting from ignorance of the laws of sanitation. The prisons in England, where the fever was frequent, were vile in the extreme. There was no fit drainage, or ventilation; and disinfection was poorly practiced, if ever. From the towns in which the prisons were, the fever would often be carried to other places. A Scotch regiment, having become infected through some prisoners, lost two hundred men. In 1750, while attending the assizes at the Old Bailey, the lord mayor, an alderman, two judges, most of the jury and many spectators caught

the disease and died of it. Jail fever has been identified as a severe form of typhus fever which, as is well known now, is caused by over-crowding and improper air, the cure being isolation, fresh air and light. The great prison reformer, John Howard, recognized the fact that the ravages of jail fever could be prevented, and he worked until he forced the world to realize it, also, and the prisons were improved. Howard was a martyr to the cause, for, after he had accomplished a vast amount of good in England, he visited other countries, bent on the same good errand and, at last, died of a disease contracted in the course of his humane work. Out of humble beginnings have grown mighty results. The perfect sanitation practiced by many governments render their prisons to-day among the most healthful abodes.

Other steps towards disease prevention were made in the Eighteenth Century. Captain Cook discovered that the scourge of the sailor, scurvy, could be kept away by a proper diet. The value of Captain Cook's methods is realized when the mortality among his crew, during a long voyage, is contrasted with that among Lord Anson's men. Out of 900 men, during a single long voyage, Anson lost 600 from scurvy. Starting out with 118 men, Cook came home, after a three years' voyage, with 114. Of the four who died, not one perished from scurvy. The early years of the Nineteenth Century saw this disease almost stamped out. In 1780 there were 1,457 cases of it received into one naval hospital in England; in 1807 there was but one case. So uncommon has scurvy become, that comparatively few surgeons in the navy, at the present time, have ever seen a case of it, while the whaling crews, which it formerly desolated, are, thanks to the superior food which they now receive, almost exempt from it.

The practice of vaccination began about 1796. It was

received, for the most part, with as intense prejudice as inoculation had been before it. Yet, during the first part of the Century, it won its way by the enormous amount of good it accomplished. The decrease in the number of deaths from smallpox was marvelous. In England, prior to 1800, the average annual number of deaths from smallpox per 100,000 of the population was over 700. After 1800 the average was about twenty-five or thirty per 100,000. Not only did smallpox kill so large a proportion of the population of England, but it disfigured or injured permanently many others. In the years before 1800, when the disease was very prevalent, most of the inmates of the blind asylums had lost their sight through its ravages. At the same time, it was calculated that fully thirty per cent of all children born died of smallpox before the end of their first year. In New York between 1785 and 1800 there were 5,756 burials in Trinity and St. Paul's churchyards; of these 610, or a little more than one-ninth, were deaths from smallpox. During the years 1805 and 1806, the population of the city having grown, there were 4,595 burials in the same two cemeteries; 110, or about one-fortieth of the entire number were deaths from smallpox. At the present time, although smallpox has not been universally banished, vaccination has reduced it to a minimum.

The progress of medical science and the enlightenment of the people at large, during the Nineteenth Century, have brought about an entirely new attitude in regard to the preservation of individual and public health. The maintaining of proper sanitary conditions and the preventing of the spread of disease are accomplished in innumerable ways. Municipal government watches over the health of the public. Boards of Health enforce regulations which have been found by experience to be necessary.

Thus in most cities it is required by law that householders and physicians notify the proper authorities of the occurrence of contagious and infectious diseases as soon as their presence is detected, and on the receipt of such notification, proper precautions are taken to prevent their spread. By prompt isolation of the patient thousands of lives may be saved. Health officers inspect the drainage systems, the water supply and general sanitary conditions of the districts under their supervision. Food and drugs are examined, and laws against adulteration are enforced. Instructions on health and science are issued to the people, and there are free dispensaries. In some parts of the world the establishment of free baths and wash-houses has had a noticeable effect on the public health, causing an actual reduction of the number of applications for admission to the hospitals.

Quarantine is the rule at seaports. All incoming vessels are inspected carefully, and no suspicious cases of disease are passed by. Thus, of late years, cholera and other dreaded epidemics have been kept out of the United States and England when they were raging elsewhere. But it is not quarantine alone, efficient though it be, which is restricting the ravages of frightful epidemics. Yellow fever is kept under by proper methods of sanitation. Even in the Southern cities of the Union changed conditions have lessened its terrors. Typhus and typhoid fever, two very different diseases, which, one hundred years ago, were not distinguished between, have each been traced to its true cause and are dealt with accordingly. So it is with many other ailments. Especial progress has been made in the discovery of the nature of zymotic diseases.

Hospitals are, by no means, an innovation of the Nineteenth Century, but until within the last fifty years hospital methods stood in great need of improvement. With

the introduction of antiseptic surgery and with the attention to nursing which is characteristic of the age, marvels have been accomplished in the way of life-saving. Improved methods of sanitation and construction are also a product of the thought and ingenuity which have been bestowed on the lodging and caring for the sick and the hurt by the leading physicians and surgeons of the day. With the specialization of the study and practice of the healing art has come a tendency to maintain hospitals for a restricted class of patients. There are lying-in hospitals, hospitals for contagious diseases, children's hospitals, hospitals for the diseases of women, consumptives' hospitals, eye and ear hospitals, hospitals for the insane, and others, each intended for the accommodation of a special kind of the ailing in mind or body. In the treatment of those unfortunate beings who have the misfortune to suffer from mental disease, the Nineteenth Century has made a great advance over previous ages. Lunatics, idiots and all of the insane or unsound in mind used to be considered possessed of devils, and, therefore, were treated harshly, often brutally. Straight-jackets, irons, coercion, chains, and other instruments of torture were the usual apparatus for the treatment of the insane, one hundred years ago. Flogging, starving, solitary confinement in dungeon or cell were all approved methods of dealing with the unhappy inmates of lunatic asylums or hospitals. These methods have been succeeded by reforms so great that the mere mention of the former state of affairs arouses indignation.

MODERN WARFARE

In all the long history of warfare, which is in reality the narrative of the world's progress from earliest time, there is no similar period in which changes so vast and far-reaching have taken place as during the latter half of the present century. There is much less difference between the naval and military methods of the Sixth Century before Christ and those of the Eighteenth Century than there is between the latter and those of the present day.

Until the middle of the present Century the difference that existed between the ancient war galley and the modern battleship was so slight as to justify the remark common among naval constructors of the day, that "naval architecture, like history, repeats itself." Until the introduction of steam, which was first attempted in 1815, in the double-hulled vessel designed by Robert Fulton, but which did not become practical for naval purposes until 1846, our men-o'-war were but a trifling improvement upon the galleys of Diodorus Siculus. The old galleys were queer looking craft. They were built with keels and frames, and contained a stem and stern post. Near the water line the stem curved outward, gradually taking the form of a ram —a weapon still used in modern warfare. They also had one or more masts, and were propelled by oars, or sails whenever the wind was favorable. Going into action was a gorgeous sight in the Middle Ages. Falcons and broad banners of gaudy hue were flung to the breeze, the sunlight flashing upon the breast-plates of the warriors drawn up in fighting order, and upon a sort of bridge or castle amidships stood a band of richly caparisoned musicians,

playing with all their might. At the bow was the battery, consisting of manogels and great cross-bows, with winding-gear that shot showers of huge stones and arrows and red-hot iron and carts of Greek fire at the enemy. Fore and aft small towers were erected, from which archers shot arrows.

Gunpowder led to the abolition of the towers, and artillery was substituted. Gradually, with the perfection of the art of sailing, the tactics of warfare were changed. During the early part of the Sixteenth Century the low galley was replaced by the sailing war vessel, and the size of the guns, which were mounted in broadside on these ships, constantly increased. With this increase there came also an increase in the size of the vessels, until, during the Seventeenth and Eighteenth Centuries, the warships became formidable affairs, with three decks and a hundred or so guns. The most deadly of these weapons was the carronade—a light piece first constructed at Carron, in Scotland. This gun was of a large caliber, short length and light weight, and its destructive effect was supposed to exist not so much in its power of penetration as in its ability for splintering. With a reduced charge of powder, and slow initial velocity, the projectile from the carronade created havoc wherever it pierced the side of the enemy. With these developments came a gradual change in naval methods, and at the beginning of the Nineteenth Century warfare was well organized for the first time in history, the crew being divided into little companies, each of which had certain duties. Besides the crew, each frigate had thirty or forty marines, whose duty it was to police the ship and prevent mutiny, which was very common until fifty years ago, owing to the extreme cruelty practiced upon the sailors. These marines were kept carefully apart from the crew, and animosity between them encouraged.

At the time of battle they were placed in the tops, where it was their duty to pick off the enemy with their muskets. In case they were able to engage the enemy in close quarters, they were expected to board the ship of the combatant, assisted by two or three seamen from each gun, the latter being armed with pistols, cutlasses and boarding pikes. These were known as boarders, and when they were called for, just so many men, and no more, ran from each gun. When the boarders took possession of a ship a fearful carnage followed. When a battle was about to be fought the decks were sanded to make them less slippery when the blood should begin to flow, and ammunition, small arms, guns and pikes were stacked conveniently near the masts and out of reach of the rivers of gore with which, each bold sailor well knew, the good ship would soon be drenched. The sailors for the most part led hard lives, and were treated little better than their predecessors, the galley slaves. Flogging was common, and many men died under the lash. The crews were generally secured through impressment, and kidnaping was extremely common, as the romances of that period attest.

Such were the ships used and such the methods of warfare generally in vogue when, less than a hundred years ago, Nelson fought and won Trafalgar, the greatest battle in British history, and the most famous of all battles fought between sailing vessels. Although neither so large nor so formidable as the frigates used by Nelson, sailing ships of the same type were used in the memorable naval engagements of our own glorious War of 1812.

The year 1840 saw the sailing ship at the very zenith of its glory. Naval authorities all agreed that further improvement in fighting craft was impossible, and all the great maritime powers of the world were constantly increasing their fleets. In 1841, however, the death-knell

THE UNITED STATES BATTLESHIP OREGON

of the sail began to sound, when the Mississippi, a bark-rigged, steam-propelled frigate was launched and met the approval of the experts. Up to this time steam had been applied only to side-wheel vessels, though Stevens had advocated the screw as early as 1804. Ericsson, however, was the first to make a practical demonstration of its utility in 1837. The screw frigate Princeton was launched in 1844, and the advantages of the propeller became too obvious to be disregarded, however much sentiment might cling to the romance and glory that seemed to cluster around the old-time craft. It was not an easy task for the sailors to give up their graceful, shapely frigates for the modern "tea kettle," as the new craft were contemptuously called, and the fight between steam and sails was a long and bitter one.

In 1857 came the era of iron ships, and the only thing now in common between the wooden vessels of Trafalgar and the modern battle ship of the Spanish-American war is that each is a water-borne structure, armed with guns and propelled in some manner from point to point. The application of armor to ships and its great value was understood by Admiral Mackau, Louis Philippe's minister of marine, as early as 1840, but was kept by him a profound secret, he intending to employ it against England should occasion arise. Ericsson, about the same date, conceived the general idea of the Monitor. In 1842 Stevens had commenced in the United States a ship plated with four and one-half inches of iron, though the ship was never launched. In the Crimean war both England and France built armored batteries of indifferent seaworthiness. These early European iron-clads were simply line of battle ships cut down, with one tier of guns, and armored on the water line and over the battery. They were no radical

departure from the established type. In 1857 Dupuy de Lome completed his famous La Gloire, the first sea-going iron-clad. But the first really effective vessel of this kind was the Confederate cruiser Merrimac, and her famous conflict with the Monitor has been called the most important naval battle in the world. The Merrimac was a cruiser that had burned to the water's edge and sunk. The Confederates raised and rebuilt her, enclosing her vitals with iron plates two inches thick. A bulwark was built, and similarly covered, and a cast-iron ram was attached to the bow about two feet under water. On March 8, 1862, the Merrimac steamed out of Norfolk harbor and encountered the wooden ship, Cumberland. The huge projectiles from the Union vessel glanced harmlessly into the water, not so much as denting the stout iron sides of the Confederate ship. The Merrimac meanwhile sent four shots into the wooden ship, and, moving right under the muzzles of her thirty guns, struck the Cumberland a terrific blow with her iron prow. The Cumberland began to sink, while the guns of the Merrimac did frightful havoc. More than one hundred of the crew were quickly killed. The water drove the men from the lower guns, but they rushed to the upper and desperately fired their harmless shots at the great mass of iron. At last, with colors flying, the Cumberland sank. Having ended one adversary, the Merrimac turned upon the Congress, which had been peppering at her, and, although the crew of the latter fought desperately, they were soon forced to surrender. The whole world was electrified by the news that flashed over the wires that night, and the North was in a panic. The next day a great surprise was in store for the Merrimac. A strange looking craft that had been derisively called the "Yankee cheesebox," steamed forth and challenged the

jubilant Confederate. The Monitor had been built after a design of John Ericsson, who for twenty years had been endeavoring to secure its adoption. It was an iron-plated raft, 172 feet over all, 41 feet beam and 11 1-3 feet depth, and with a revolving iron turret containing two guns. The target surface was reduced to a minimum, the hull being less than two feet high and plated with five inches of iron. The turret was nine inches high, and covered with eight inches of iron. It was a floating fortress.

It seemed at the time impracticable, but in desperation the United States was willing to try the experiment. Naval experts believed that the first shot fired by her own guns would send her to the bottom. The Merrimac had ten guns to the Monitor's two, and her crew was six times as numerous, so the people who watched the battle from the shore expected the Confederate cruiser to sink the audacious little craft with one volley from her big guns. The advantage was with the Monitor, however, throughout the entire fight, for the Merrimac could not easily reach her enemy through the narrow port holes, but the Monitor with her revolving turret could fire in any direction. The Monitor's size prevented her from being struck by many balls, and most of those which did hit her turret glanced harmlessly into the water. Though the Merrimac fired twice as many shots, those of the Monitor did the greatest execution. When the Merrimac tried to ram the Monitor she did no damage to the enemy, but opened her own bow and made an alarming leak. Not until the Merrimac's shots were directed against the Monitor's pilot house did the latter ship withdraw, and the Merrimac, leaking badly, and supposing the fight was over, also withdrew. Although the fight was undecided, the purpose of the Merrimac was defeated. The most important effect of the battle, aside from its being a virtual victory for the

Union, was the establishment of the value of the iron-clad. Ericsson's despised plan was received with enthusiasm, and a dozen monitors were quickly constructed, which were of great assistance to the Federal forces. A revolution instantly took place, not only in the navy of the United States, but in those of all the foreign powers. The building of iron-clads became imperative, and the great wooden men-o'-war, once the boast and pride of maritime nations, were now consigned to the past, along with the galley and the sailing vessel.

As soon as the iron-clad became an assured success, the nations began to look for a more formidable weapon than the ordinary cannon. This has been found in the torpedo, the most terrible engine of destruction that the mind of man has conceived for the purpose of warfare. From the floating kegs loaded with charges of gunpowder, which Captain David Bushnell set adrift in New York harbor to the consternation of the British during the Revolution, the torpedo has advanced by rapid stages to the dignity of a machine capable of demolishing in an instant the largest and most powerful battle ship afloat. The torpedo properly dates back to 1846, when Professor Schoenbein, of Basel, Switzerland, produced the powerful explosive known as gun cotton, by subjecting common cotton to the action of nitric acid. For a long time, however, this terrible explosive was impractical for military purposes, owing to the peril attendant on its transportation, but at last F. A. Abel devised a process for its manufacture in compressed solid cylinders, which can be stored and transmitted with safety, and which explode with great power when ignited under the confinement of a detonating powder. The torpedoes of modern warfare are of two kinds: They are either contrivances propelled through the water so as to strike the enemy's vessels, or are more or less stationary,

submerged mines, so arranged as to explode when a ship passes over them. During the last two years of the Civil War, the torpedo service of both forces was responsible for tremendous destruction. Seven United States ironclads, thirteen wooden war vessels, and several army transports were destroyed by torpedoes, and eight more vessels were badly injured. Four of the Confederate vessels were destroyed by their own mines. In the Russo-Turkish war of 1877-1878 the torpedo played a great part. Through their agency the armored fleet on the Danube was held in check without the aid of a single Russian war ship. At Batoum a steamer was blown up and sunk by a Whitehead torpedo, which is the first recorded triumph of that now celebrated weapon. In the Chilian revolution of 1891 the battleship Blanco Encalada was sunk with a crew of 150 by a Whitehead torpedo. The right to use this torpedo has been purchased by the leading maritime nations of the world. The torpedo consists of a cigar-shaped case of phosphor bronze. The dimensions vary in different countries, but the average length is 14 feet and the average diameter 14 inches. The destructive effect is accomplished entirely by a head, wherein lies all the way from sixty or seventy to 250 pounds of gun cotton. There are many types of the offensive torpedo similar to the Whitehead, but the complexity of their construction, and the large percentage of failures in their attempted runs, as conspicuously demonstrated in our late Spanish-American war, do not justify their being considered so much a destructive as a demoralizing power.

During the progress of hostilities between the United States and Spain, the whole naval world looked forward with breathless anxiety to see a practical test of the terror-inspiring torpedo boats. But opportunity for a demonstration of their destructiveness did not come. The Spanish

craft that sped out on their death-dealing missions at the battles of Manila and Santiago were not alert enough to escape the vigilance of the expert American gunners, who hammered them with shot and shell before they approached near enough to discharge their doom-sealing weapons. The torpedo boat has been likened to the race horse of the steamer world, built for short dashes at high speed. The first qualification is that it shall be built as small and light as possible, and that it shall be painted a color that will blend with sea and sky at night. Five-sevenths of the boat is taken up by machinery and coal, and in the other two-sevenths, the extreme ends, the boat's crew are huddled like sheep in a pen—officers forward, men aft. The hardships that are undergone by the crew of a torpedo boat during an engagement are inconceivable to anyone not in the service. The heat from the engines is terrific, and when the weary sailor is overcome by the fatigue and excitement of the battle, there is no place for him to lay his head except the narrow space between two boilers or torpedo tubes.

The defensive torpedo, however, has become the essential auxiliary of the land gun for the defense of harbors. The modern submarine mine has reached a stage of perfection that guarantees the safety of almost any city that is under its protection, notwithstanding the fact that Admiral Dewey sailed into Manila Bay over a veritable nest of deadly torpedoes. The mines are usually arranged to be fired at will or automatically at touch of the vessel. The blowing up of the United States battle ship Maine in Havana harbor on the night of February 15, 1898, and the killing of 268 brave American sailors, is the most notable example of the destructiveness of the submarine mine.

The use of solid shot in warfare has been practically given up. The projectile of to-day is a conical shell of

steel, hollow, and sometimes loaded with powder, so as to explode on striking, or by a time fuse. It is wonderfully different from the shell of twenty-five years ago. In those days one could watch the shell as it sailed through the air in a graceful curve, and there was time, under favorable circumstances, to get out of the way before it bursted. But the new style of shell moves at the rate of a mile a second, and when it strikes a metal target, its energy being transformed instantaneously into heat, it becomes red hot, and a flame bursts forth from the point struck. The projectile of to-day moves almost in a straight line, and its impact at a distance of a mile seems almost simultaneous with the discharge of the gun. When such a shell passes near a man it will tear his clothes off, merely from the windage, and if it comes too near him, though not hitting him, it will kill him. He drops dead without the sign of a wound. The concussions from their own shots destroyed the aural membranes of a number of gunners in our late war, who had not properly protected their ears against such danger.

The first real and complete test of the ordnance developed by modern naval science since the Rebellion was given during the war between the United States and Spain. Each of the contending nations had navies that included some of the best battle ships in the world, and each was splendidly equipped with all the latest improvements in ammunition and armament. The only fault with the test is that the Americans were so much superior to the Spanish in the skill with which they manœuvred their ships and handled their weapons of destruction, that it cannot after all be taken as a wholly fair test. One thing sufficiently established, however, was the effectiveness of the modern war vessel and its death-dealing power.

Improvement in modern warfare is not confined solely

to naval methods and equipment. There has been a vast change in army ordnance within the past Century. Napoleon, greatest of modern warriors, would be no more astonished than Admiral Nelson were he to return to earth and see with what strides the science of war has advanced during his absence. He would find that his heavy columns could not be launched in all their imposing pageantry; and that Murat, his daring cavalry leader, could not ride over an army with his horsemen. The grand and picturesque bayonet charge is a thing of the past. We have in its place the thin skirmish lines, seeking to crush the enemy with their fire alone, and it is probable that cavalry will never again charge on the battlefield. The simple artillery pieces that were used at the battle of Waterloo were mere toys as compared to the rapid fire machine guns of the present day. The modern machine gun is the outcome of a series of evolutions in armament. The "mitrailleuse" came first, and soon showed its capabilities. Then the Hotchkiss showed the possibility of using heavier and larger projectiles. The modern rapid-fire gun was merely a product evolved from the "mitrailleuse" and the Hotchkiss, and the rapid-fire guns differ from each other in detail rather than in results. All carry heavy projectiles and discharge such shot with a rapidity that depends largely upon the caliber of the barrels, the larger the caliber and the longer the barrels, the slower the discharge. In this country the multi-barrel has been the most familiar type, owing to the use of the Gatling gun in the army. Besides the Gatling, there are the Gardner, the Maxim-Nordenfeldt, the Accles and the Robinson, among the leading multi-barrels, while the best known single-barrels are the Maxim and the Skode. Tests with the Maxim gun have scored records of 775 shots to the minute.

The practical test to which "smokeless powder" was

put in the Spanish-American war demonstrated so obvious a superiority for it over the best of the old style composition, that it will doubtless hereafter serve all branches of military service, including vessels of war. The party using the ordinary powder could not discern the attacking foe, using the new explosive, with any certainty, till it had advanced within 200 yards of the defending line. With rifles that kill at two miles, as an Austrian improved rifle is said to have done recently, and smokeless powder in cartridges for "magazine" or "rapid-fire" rifles, with Gatling machine guns, and revolving cannon, the land forces are certainly as well equipped for war as are the marines.

Gun cotton, which made the torpedo effective, was first used for artillery purposes by the Austrian army, and is now an indispensible agent in the conduct of military and naval operations among all nations. In 1847 another and more terrible explosive than gun cotton was discovered by Sombrero. This was nitro-glycerine, and was produced by subjecting common glycerine to a treatment of concentrated sulphuric and nitric acid. The clear, oily, colorless, sweetish liquid thus obtained would burn without detonation, but when an infinitesimal quantity was exposed to the open air a jar or shock was sufficient to produce an explosion of such terrific force as to blow to atoms everything in the vicinity. In the same year Alfred Nobel, a Swedish resident of Hamburg, became greatly interested in the perilous discovery, and, assisted by his brother, began its manufacture on a large scale. Although the life of the brother was sacrificed in one of the earliest experiments, Nobel persevered until he had devised a process whereby nitro-glycerine could be manufactured with comparative safety. In 1863 he introduced the practice of soaking common gunpowder in it for blasting, and in 1867 he conceived the idea of mixing it with some solid, inert sub-

stance, such as silicious ashes or infusorial earth. The product resulting from the latter process was called dynamite, now regarded to be the safest of all explosives, as neither electricity, light nor ordinary shocks causes it to explode.

Of the numerous explosive bodies that have been discovered during the present Century, the only one that can be considered a rival of gunpowder is the substance known as cordite. This is a smokeless powder, and consists of a mixture of gun cotton, nitro-glycerine and vaseline. In the manufacture of old-fashioned gunpowder many changes have taken place within the past forty years, both in process and general composition. By increasing the density of the grains, thus closing more tightly the pores through which ignition penetrates their mass, the energy of gunpowder has been increased and the velocity of the projectile propelled thereby is proportionately increased. Another improvement of great advantage consists of molding the grains into definite geometrical forms. Instead of the more or less coarsely pulverized substance of a half century ago the gunpowder of to-day is made into prismatic, lenticular, pellet and hexagonal forms. One of the most popular varieties of these forms is the hexagonal prism. It was chosen for the same reason that the honey bee chooses to build hexagon cells in its comb—to economize space. In building cartridges for big guns out of this powder the pieces fit snugly together, every possible ounce of force being put into the prism by compression. There is accordingly no loss of space in the load chamber of the gun. The concentration of power by means of the hydraulic press used in the manufacture of these prisms is so great that solid prisms of this powder loaded into a gun would burst it. To obviate this each prism is perforated with a number of small holes running parallel

to its axis, thereby securing expansion equally in all directions and insuring the combustion of all the explosive.

One of the most marvelous institutions of modern warfare is the transmitting of intelligence by means of sunlight signals, or heliographing. The system of the heliograph is extremely simple. It employs a mirror much more carefully prepared, but not much bigger than the bit of looking-glass wherewith the mischievous schoolboy throws flashes of sunlight into other people's faces, and it works on the same general principle. A great deal has been done in late years to adapt the telephone and telegraph to troops in the field, but time and opportunity for constructing even a temporary line across a stretch of hostile country or regions exposed to the fire of the enemy is often lacking. It was formerly customary to resort to the flag by day and the torch by night, a certain signal code being brought into requisition. But the torch and flag were unavailable for greater distances than ten to fifteen miles, and in rainy or dark weather their use is limited to five miles or less. Sometimes two mirrors are necessary in order to work a heliograph. This is called the duplex system. When the sun is behind the signaller, a second mirror is placed at such an angle that the reflections are thrown on the first, or working mirror. At night the instrument is rendered equally effective by adjusting the mirrors so that they reflect the light produced by a powerful electric arc. The heliograph first demonstrated its efficiency and utility for field intercommunication in the Indian wars of the Western frontier, beginning in 1886. Three years later Major W. J. Volkman, U. S. A., demonstrated in Arizona and New Mexico the possibility of carrying on communication by heliograph over a range of 200 miles. He was assisted by 33 officers and 129 operators, and 3,787 messages were exchanged, comprising

92,406 words. The network of communication begun by General Miles in 1886 and continued by Lieutenant W. A. Glassford was perfected in 1889 at ranges of 85, 88, 95 and 125 miles, over a country inconceivably rugged and broken, the stronghold of the Apache and other hostile Indian tribes.

The use of the balloon in warfare is another distinctly Nineteenth Century institution, its first recorded application to such purpose taking place during the Civil War. In 1862 General McClellan organized a balloon corps, with Thaddeus S. C. Lowe at its head. The innovation soon became a component part of the Army of the Potomac, as it did good service in disclosing the military operations of the Confederates. Now all the leading military nations of the world have their balloon corps, specially trained and equipped for reconnoitering purposes. At the battle of Santiago on July 1, 1898, the movements of the enemy were observed from a balloon by Sergeant Thomas Carroll Boone. A telegraph wire connected the basket of the balloon with the ground, and observations, transmitted in that manner to the officers below.

The bicycle has also been brought into requisition as a piece of army equipment in recent years, and a number of the leading military powers of the world have fully equipped bicycle corps attached to their regular armies.

The practical abolishment of privateering constitutes one of the most wholesome and radical changes that has taken place in modern warfare during the present Century. This marked a long step in progress, for as a matter of course privateering is but a legalized form of piracy. Although privateering in some form or other goes back to ancient times, the "sea beggars" have flourished especially as a recognized institution of civilized nations from the middle of the Sixteenth Century to the close of the Rebel-

lion. The privateer was an armed vessel belonging to a private owner, the subject of a belligerent power, and bearing a commission from that power to "sink, burn or destroy" the commerce of an enemy. With its abolishment by the Treaty of Paris in 1856, the last vestige of poetry and romance has departed from modern warfare. The day of smart manœuvres under sail, of yard-arm to yard-arm conflicts, of the carronade, swivel and boarding pike, is now a thing forgotten. The dare-devil style of climbing over a stranger's bulwarks, clearing his decks with naked cutlass and spitting pistols, and then asking his nationality and destination, is also forgotten, although it is but comparatively few years since such practices were extremely common. The Eighteenth Century and the early years of the present were halcyon times for the privateer. The New York newspapers of the Colonial period abound in advertisements inviting "gentlemen and others" to enlist with this or that vessel fitting out under the commission of "His Majesty." England encouraged privateering by ordering that prizes taken should be divided between the owners and the captors, the rights of the crown being especially excluded in numerous prize acts. The United States, as a nation, also greatly encouraged privateering up to and during the War of 1812. Not less than 1,367 public and private armed vessels were commissioned by the colonies to prey upon British commerce during the Revolution. In spite of its prevalence and immeasurable advantage to the United States during the War of 1812, privateering soon fell into disfavor, as shown by the fact that Congress in 1818 passed a law forbidding the enlistment in this country of men for foreign privateering. Great Britain was more than fifty years behind us in passing such a law. In 1824 the United States vainly urged Great Britain to assist us in the abolition of

legalized sea robbery. Thirty years later Lord Clarendon advised that it be abolished by international agreement, but James Buchanan, then United States minister to England, was instructed to reply that his country could not assent to the proposal unless all the naval powers should declare that war should never be waged upon private property on the high seas. In April, 1856, at the termination of the Crimean War, Great Britain, France, Austria, Russia and Turkey held a congress at Paris, at which it was decided to abolish privateering under the agreement known as the Declaration of Paris. This notable congress was brought about by Great Britain because it was feared that Russia would issue letters of marque to the fleets of the United States merchant ships, commissioning them to prey upon English and French commerce. All the important European powers save Spain signed this treaty, and all the American powers except the United States and Mexico. This country, through William L. Marcy, offered to sign the agreement if the clause as to privateering should be amended by the declaration that the private property of subjects or citizens should be exempt from seizure on the high seas by the public armed vessels of other belligerents. The great powers refused assent to the proposed amendment, and the United States did not become a party to the treaty. When the Civil War broke out in 1861 Mr. Seward, then Secretary of State, offered to sign the treaty of 1856 without insisting upon the amendment, but Great Britain and France replied that the signature could not be accepted if it was to be coupled with the condition that the provisions of this treaty were to be made applicable to the use of privateers by the Southern Confederacy. As that was the wish of the administration Mr. Seward did not sign the treaty. The story of Confederate privateering, and especially the damage done

to commerce by Confederate cruisers, was still fresh in the memory of the world when the American-Spanish war broke out. The fact that neither of the contending nations had signed the Declaration of Paris, and were therefore at perfect liberty to issue letters of marque and reprisal to privateers was looked upon with grave forboding by all the great maritime powers of the world. Although Spain threatened at the outbreak of hostilities to resort to such method of warfare, it was never carried into execution. Civilized opinion was too strong against such barbarous and illicit practice to warrant its being carried on with any success, and the opportunity for disposing of prizes would have been greatly restricted by the almost undoubted refusal of neutral nations to permit such spoils of war to be sold in their ports. Trade relations have become so much more important than they were in the days of active privateering that the day has long gone past when the world would stand by and see two belligerent nations preying upon each other's commerce to the annoyance and inconvenience of all their neighbors.

Up to the present Century the most inhuman methods of punishment for breaches of discipline were in vogue both in the army and the navy. The military punishments in the English army were of infamous severity. Instances were numerous where a thousand lashes were given to offenders, while riding the wooden horse, being strung up by the thumbs and other equally cruel punishments were very common. All these brutal chastisements have been done away with, and only in very rare cases is any physical punishment administered to the modern soldier or sailor. In the year 1850 flogging was abolished by act of Congress in the navy of the United States. Up to that time the captain of any of our national vessels had the authority, at his discretion, to order any man in his com-

mand to be stripped and lashed with the cat-o-nine-tails. This instrument of torture, once so familiar to all seafaring men, is now only known to them by tradition. Old officers thought the navy itself as good as abolished with the cat-o-nine-tails. But subsequent events proved how utterly mistaken they were. The record made by the naval forces under Farragut in the Civil War and under Dewey at Manila are proof positive that the fighting qualities of the American Jack Tar have not been spoiled in the least by the sparing of the cruel and barbarous weapon.

Since the introduction of more humane methods of treatment, statistics show that both the sailors and the soldiers of the world are gradually growing better, and that there is a gradual decrease in the number of court-martials. The last report of the Judge Advocate of the United States Army shows a marked decrease in the number of court-martial trials since 1893. With the improvement of the morale of the army it is interesting to note that the desertions have fallen off wonderfully. In 1894 there were 518 deserters; in 1895 the number fell to 255; in 1897 it dropped to 244; and in 1898, when there was real fighting to be done, it fell to 176—and that out of an army that was nearly twice as large as it had been in 1894.

However paradoxical it may appear, it is nevertheless a fact that the improved destructiveness of weapons of war has made a less destruction. The modern conception of war with the more advanced nations includes the factor of fighting with the least possible suffering, and to meet the demands of the accepted standard of humanity has been the purpose of the newer engines of destruction. It was with this humane intent that the Mauser bullet was invented. The old-fashioned bullet usually whirled round and round, tearing the tissues, arteries, muscles and flesh, and on coming in contact with a bone shattered it to

splinters. The wound of exit left a hole large enough to insert a man's fist. Whenever a man was hit in the arm or leg with one of these bullets it was almost always necessary to perform amputation, if the victim did not die beforehand from hemorrhage. With the Mauser bullet all this is different. Experience in the Cuban war has demonstrated that only very infrequently does a wound caused by a Mauser bullet result in a hemorrhage which might be fatal. Men struck by the Mauser bullets have been known to continue fighting to the end of the battle after receiving what is generally supposed to be a mortal wound. In almost every case this bullet passes clear through the victim's body, and the wound of exit is no larger than that of entrance, and there is no splintering of bone or tearing up of tissues.

All the changes that might be supposed to make war more cruel and bloody have really operated in the interest of humanity. The old-fashioned arms, because they were fired at close quarters, killed and wounded sixty per cent of the combatants. The improved arms of modern warfare, in the bloodiest battle noted in history, killed and wounded but little more than 25 per cent. The "laws of war" show a magnanimous consideration for the enemy and a humane regard for the weak and the defenseless. According to the code at present formulated by civilized nations these laws forbid the use of poison against the enemy; murder by treachery, as for example, assuming the uniform or flag of the foe; the murder of those who have surrendered; the use of such weapons as will cause unnecessary pain to an enemy; the abuse of a flag of truce; all unnecessary destruction of property, whether public or private; that only fortified places shall be besieged; that women and children and non-combatants be allowed to depart before the bombardment of a city begins; that plundering by

private soldiers or officers shall be considered inadmissible; that prisoners shall be treated with common humanity; that personal and family honor and the religious convictions of an invaded people must be respected by the invaders, and all pillage by regular troops or their followers be strictly forbidden.

Considering the marvelous strides which modern warfare has made in the Century, it may appear to some that the universal brotherhood of man is but an empty dream, and that the day is yet far distant when the nations of the earth shall beat their swords into plowshares, and their spears into pruning hooks. Paradoxical as it looks, we are rapidly tending towards a practical millennium. On account of the enormous expense necessary to conduct campaigns in these advanced stages of equipment, wars are much shorter in duration and more infrequent of occurrence than they have ever been in the history of the world. In fact war has come to be regarded as such a terrible ordeal that it is only resorted to after every available effort has been expended to settle the dispute by arbitration. This method has been gradually growing in favor among all nations, and as a result more than eighty international disputes have been settled by arbitration during the Nineteenth Century. The people of the world have risen up in revolt against the tyranny of needless conflicts, and war is now compelled to give a strict account of itself and to answer a thoughtful and stern challenge for its reason for being.

PRINTING AND PUBLISHING

In these days of printing presses that turn out acres of thought transferred to paper quicker than the twinkling of an eye, it is strange to think that the beginning of all this complicated machinery of to-day was so recent as 1803. Books, magazines and newspapers are so cheap and plentiful nowadays that it is impossible to realize that in the "good old times," less than a hundred years ago, the library of the man of average intelligence and moderate means generally consisted of nothing more than Pilgrim's Progress, Fox's Book of Martyrs, Johnson's Dictionary and the Bible. This meager catalogue was sometimes supplemented by a copy of Shakespeare's plays, or a book of poems, either of which were literary treasures that conferred upon the owner no small measure of distinction among the appreciative inhabitants of sparsely settled and bookless communities. This paucity of reading matter was by no means confined to the illiterate lower classes. The biography of almost every great American statesman or author of a generation ago, bears ample testimony to the fact that books were, in his youth, considered a luxury, and that their acquisition, in any great numbers, was a privilege enjoyed only by the wealthy. Magazines were practically unknown, and the few that did exist were necessarily high priced. The newspapers, erroneously so-called, were diminutive, poorly printed sheets, containing stale "news" prepared in a more or less ludicrous style. How great a misnomer the term "newspaper"

was in those days can be readily understood when we read the Boston News-Letter's regret over being thirteen months behind time in supplying European intelligence. Very frequently the newspapers were delayed several weeks in their appearance owing to lack of paper. As soon as one of these paper famines threatened the press, its patrons were notified of the fact by conspicuously printed appeals to the "fair dames and maidens" respectfully begging the privilege of purchasing their "worn-out frocks, petticoats, and such other discarded raiment as might contribute to the composition of paper," and indicating when the "ragman" would call to make collections.

Such were the conditions a hundred years ago. And now what a marvelous change! A library of generous proportions is within the reach of the humblest working man who earnestly desires it. Magazines and periodicals of the highest literary excellence and artistic design may be bought for considerably less than the proverbial song, and of newspapers it will suffice to say that they are indeed well named when they can keep us posted from hour to hour of the progress of human events in the uttermost parts of the earth.

In reviewing the great inventions of the century which contribute so largely to the cheap dissemination of literature, it is most fitting to consider first the marvelous progress that has been made in the field of book and magazine making. Here a complete revolution has taken place—in methods of printing, in illustration and in machinery and processes for binding and covering. Up to 1813 very little progress had been made in the making of books since the days of Gutenberg or of Caxton. For a period of 350 years all printing was done on the old platen press, the almost identical counterpart of

Gutenberg's invention. The press used by Benjamin Franklin, now exhibited in the National Museum of Washington, is a fair type of the platen style of printing press. A brief description of it and the methods employed in its operation may give an adequate idea of the crudity of the industry as it obtained up till the beginning of the present century. The press is constructed almost entirely of wood, and consists of a flat "type bed" upon which the "form" (the type) is placed, above which is suspended the "platen" or impression plate. The bed is rolled under the platen by the "rounds" (a wooden cylinder and straps). To the platen is attached an impression screw by which power is applied when it is desired to make an impression; a pulling of the handle causing a revolution of the screw, forcing the latter down upon the type bed. The press, of course, was operated entirely by hand, and the marks of the statesman-printer's ink-besmeared fingers are impressed upon the clumsy frame. The type was inked with what were known as inking balls. These consisted of large round pads or balls of leather stuffed with wool. These balls were charged with ink and rubbed briskly one upon the other until there was an even distribution of the printing fluid. Then the apprentice applied them to the face of the type with both hands until the letters were uniformly inked. It is in connection with this process that the term "printer's devil" had its origin. The manipulation of the inking balls being the most disagreeable task in the old-time printing office, it was always consigned to the newest apprentice, in most cases a raw and awkward youth, who in his first endeavors invariably succeeded in getting more ink on his face, hands and clothing than on the balls. The appearance which he presented with visage besmeared with the

black fluid was extremely suggestive of his satanic majesty, and that title became the inheritance of the printer's apprentice and so remains to the present day, although the inking balls have long since been consigned to oblivion. In 1798 the Earl of Stanhope made a press entirely of iron, which was an improvement, though not a radical one, over the machine used by Franklin. The frame was cast in a single piece, and the power was applied by a combination toggle joint and lever. The machine was able to turn out about 250 impressions per hour, and was considered a marvel in those days.

In 1803 two new principles were discovered, which in their development and modification have made the marvelous product of the presses of to-day possible. During that year Frederich Koenig, a Saxon, commenced experiments with the view of rendering the then existing hand press more rapid and useful. His idea was to substitute the composition roller for the inking balls, and the impression cylinder for the platen. After years of experimenting he finally succeeded in inventing a machine embodying both of these principles, and to be operated not by hand power, but by steam. In 1812 Mr. Walter, proprietor of the London Times, ordered two of these machines and had them secretly erected in the very next room to that in which the paper was being printed by hand. He was obliged to conduct the work clandestinely, as he had already experienced considerable trouble with his workmen, who opposed every improvement that was likely to interfere with hand labor. Under these circumstances the work of construction progressed very slowly, and it was not until two years later, at 6 o'clock on the morning of November 29, 1814, that Mr. Walter entered the press room of his office with several damp, printed sheets in his hand, and informed

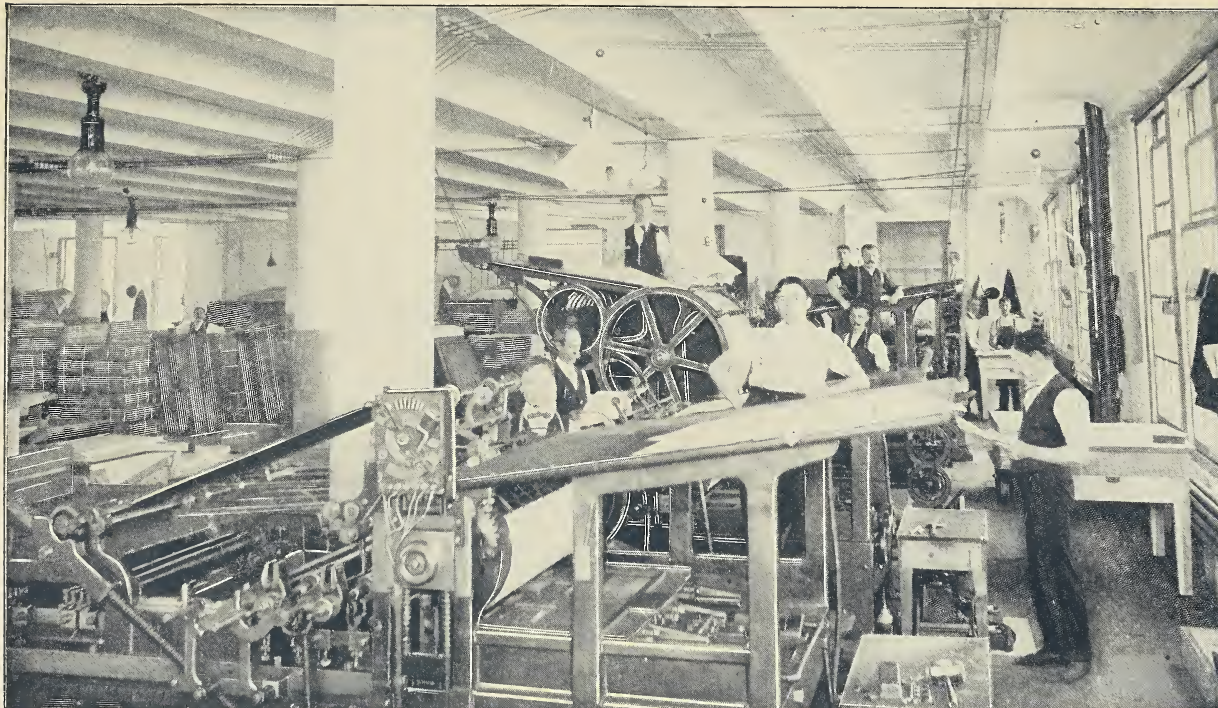
the astonished hand pressmen, who were waiting for the "forms," that the edition of the Times for that day had been printed by steam. This press was capable of turning out 800 copies of the Times in an hour—a marvelous production in that time. Each of the machines erected by Koenig for the Times printed only one side of the paper, so that when the sheet had been half printed by one machine it had to be passed through the other in order to be "perfected." The first improvement on the Koenig press was made by Cowper and Applegath, who contrived a modification by which both sides of the sheet could be printed in one and the same machine. The principles of the Koenig and Applegath machines have been followed, with more or less diversity of detail, in most of the printing machines at present in use for ordinary book and magazine work.

Until quite recently many of the very finest books, where it is necessary to have great clearness and definite color, were done by platen presses constructed after the Stanhope model. The successive improvements on the Stanhope press were the Columbian, introduced in 1817, in which the power was applied by a compound lever; and the Washington, invented by Samuel Rust, in 1829. In 1830 Adams applied the principle of the hand press to a machine operated by steam and known as the Adams book press, capable of giving 5,000 and 7,000 impressions per day of good book work, the impression being given by raising the bed upon which the form rested against the stationary platen. The latter has superseded other platen presses. In the first stages of their mechanical construction, the processes of making the ordinary book are identical to those used in magazine work. The Adams presses are still used in some degree for this work. But the presses in general use are

the flat-bed cylinder and the rotary perfecting press. Flat-bed presses use sheets of paper made to some definite size to suit the book. The rotary perfecting press is necessarily printed from rolls of paper and cut on the printing machine to the required size.

As the work required for magazines and books is quite different from newspaper work, the speed at which the rotary book perfecting press is run is much slower. The advertising and plain text forms are run at the rate of about 6,000 sheets per hour, each sheet containing either thirty-two or sixty-four pages. As the cuts and half tones have to be printed upon clay-coated and calendered paper, which cannot be put up in rolls, this kind of work has to be done on the flat-bed presses. There is used at the present time, in connection with these flat-bed presses, a marvelous automatic mechanical device known as a "feeder," which does the work once done by hand feeders.

Probably the most remarkable of these machines is that invented very recently by George F. Leiger, of Chicago. It takes on a maximum load of about 20,000 sheets, thus assuring a run of about two days for the press without reloading. The table holding the load of paper rises automatically to correspond with the sheets as fed off, thus keeping the top of the pile always at the same level. By means of a suction pump a vacuum is formed of sufficient force to pick up the heaviest cardboard, or it can be adjusted so finely as to pick up the thinnest paper. This makes the machine a great boon to the book-making industry, as it gives the machine a range from French folio to cardboard, something no other feeding machine has yet accomplished. The vacuum is carried through a series of pipes to the "pick-up" fingers, which come in contact with the sheet of



MODERN PRESSROOM

paper at each of the four corners. The vacuum is cut off and again put in use by means of irregular cams so timed that the fingers release the back end of the sheet before the forward fingers let go. The latter remain in contact long enough to allow a forward movement to engage the sheet with a series of rollers connected by tapes, which conduct the sheets to the guides and grippers of the press. In order that the sheets cannot be held together by electricity, as is often the case, a continual current of air circulates between the top sheet and pile by means of blow pipes. Should two sheets, or a badly wrinkled sheet, pass down to the guides, the machinery is instantly stopped by another ingenious contrivance, so that it is impossible for two sheets or an imperfect sheet to pass into the press. With the saving in labor and the increase in production over hand feeding the earnings of a printing press are about 25 per cent greater with the aid of this automatic device.

From the presses the paper is carried on trucks to the folding machines and loaded, in lots of from 6,000 to 8,000 sheets at a time. These folding machines also are among the most wonderful labor saving devices of the age. These modern folding machines are of three or four different makes and do their work in various ways. One is known as a quadruple folder, another as a double sixteen folder, and another as a four-eight folder. Automatic feeders are also used to deliver the sheets to the folding machines at the rate of 3,000 per hour. The quadruple folder takes the sheets as delivered by the feeder and folds the sixty-four pages, cutting and delivering the same in four separate sections of sixteen pages each. The double sixteen folder takes the clay-coated sheets with the cuts, consisting of thirty-two pages, cuts, folds, and delivers the same in sections of

sixteen pages each, collecting each sixteen page separately or inserting one within the other when desired. From the folding machine the sheets are taken to a hydraulic press, where they are subjected to a pressure of 70,000 pounds. The process compresses the paper for convenience in handling through the subsequent stages of the work. The folded sheets are then laid upon tables, where girls take one of each section until the full book or magazine is gathered together. This work is all done by hand. After the sheets have been gathered into a complete book, they are wire-stitched or sewed with thread by machines and sent to the covering machines. This cover machine puts the covers on magazines at the rate of 25,000 copies per day. The books are fed into a clamp at one side, and are let down, one at a time, and passed over wheels that rub glue on the back, and as each book comes along the platform on which the covers are piled automatically rises and presses a cover against the book, which is then carried along until it comes in contact with iron presses, fastening the cover still more firmly.

In the process for binding in cloth or more expensive material, the folded sheets are pressed solidly together by the smashing machine, whence they pass into the sewing machine, and then to the trimming machine, which trims the three sides smoothly and accurately—a work that was formerly done altogether by hand. The next process is to round the backs, a thin coat of glue previously applied holding the round in shape. A piece of muslin is then put over nearly the entire length of the back and extends an inch or so over the sides. If the book is to have gilt, sprinkled or marbled edges, those are the next processes. A number of the books are secured between two boards. The fine dust-like coloring

seen on the edges of books is obtained by sprinkling the color selected on the upturned edges with a large brush. In marbling, the fine colors are mixed by the workmen and are dropped on the surface of a long pan especially constructed for the purpose and partially filled with a mucilaginous mixture. The colors remain on the surface and are given their blending and beautifully formed shapes by "combing." The edge of the book is then dipped sufficiently to take up the colors from the surface of the mixture. If the edges are to be gilded, they are scraped smooth and dusted with red chalk. The size on which the gold is laid consists of albumen and water, and the burnishing is done with a bloodstone or agate. In cloth-bound books the cases are made almost entirely by machinery, the cloth and the boards being cut to the exact size; the cloth is then glued on the boards, and the case is then ready to be embossed in the style desired, then the book is "cased in" and put in the standing press to set it.

Besides the innumerable mechanical inventions in the way of printing machinery, folding machines, feeders, type-setting devices, etc., all of which have considerably cheapened the production of books and magazines, there have also been devised a vast number of processes for printing and illustrating. Of printing processes, the most important in book and magazine work is that known as electrotyping, introduced about 1840. At first the results were full of imperfections, but now the method is in universal use for book making and woodcut illustrations. If electrotype plates were not used, after a few thousand impressions both the type and wood cuts would become worn and damaged to such an extent that they would be useless. Their reproduction entailed a great expense of time and money and

the only way the publisher could reimburse himself was to place a correspondingly high price on his book. As it is now, few books are printed from movable type unless it is absolutely certain that no reissue will be required. The mold used for electrotyping is made of wax, the wax is melted for the purpose and poured into shallow pans and after it has become solid a treatment of finely powdered pure black lead is applied. The latter is sprinkled over the surface and any excess is removed by blowing of bellows. The wax thus prepared is placed in contact with the type form or wood cut, which have also been covered with black lead, and a powerful press is applied. In a few minutes the wax takes a sharp impression, embracing all the most delicate details of the work, and becoming at the same time very hard. Black lead is then applied to the face of the mold with a soft brush, then it is put into a battery consisting of a solution of sulphate of copper, and upon being removed after some hours the black leaded surface is covered with a compact deposit of copper in which is reproduced the most minute details of the engraved block or letter-press form. The wax is removed from the copper plate by exposing the molds to a gentle heat. The thin copper shell is tinned on the back and a molten metal poured on to the depth of about one-eighth of an inch. This is called backing, and gives solidity to the copper plate. After it has been screwed through a block of wood of specific and accurate fitness, the plate is ready for the printers' hands.

Modern methods of illustration began about the beginning of the century, with the discovery of the art of lithography, which happened as follows:

Aloysius Senefelder, a musician employed in one of the theaters in Munich, was arranging his musical com-

position on a slate formed of flakes of limestone, when by accident the score he was thus preparing was knocked into a slop-bucket full of greasy water. When the slate had been recovered he was surprised to see that the grease remained upon the musical characters, while the background of the stone was comparatively clean. A brilliant idea struck the musician, and he set to work with enthusiasm. Within four years from his first observation he had succeeded in contriving a suitable press for taking impressions, and in securing proper crayons and appropriate acids for acting on the stone. Although he guarded his secret jealously, it leaked out, and a number of persons, through experiment, succeeded in rediscovering the art for themselves; so that Senefelder never profited by his invention. In 1810 the first lithographic press was established in London by Mr. Hullmandel, and its value as a means of multiplying works of art became generally recognized.

Although it required years of patient endeavor to perfect the art, it is simple enough. The stones used in the process, the best of which come from Germany, are prepared by rubbing one slab against the other with sand and water. If the stone is to receive written characters it is polished by means of pumice stone, but if it is intended for a drawing the stone is grained by means of the friction of a finely-sifted sand. If it is desired to reproduce written characters or drawings done with a pen, lithographic ink is applied with a fine brush or a pen, as the case may demand. The ink is composed of wax, gum-mastic, gum-lac, lampblack, and soap. The professional lithographer must possess a great amount of dexterity, as it is necessary for him to write the characters on the stone in a reversed position. In order to see the characters in their usual position a looking glass

for viewing his work is used. For drawing, a lithographic crayon is used. The composition of this crayon differs, but is usually of soap, wax, grease and lampblack with other minor ingredients. Exactly the same method is followed as in the reproduction of written characters, save the necessary reversals. After the design has been placed on the stone, a mixture of nitric acid and gum is allowed to run over it. This process renders all parts of the stone not protected by the ink or crayon incapable of receiving ink, while at the same time it more strongly fixes the outlines of the drawing. After being thoroughly cleansed of any traces of foreign matter, the stone is subjected to a treatment of turpentine, which apparently obliterates the very design itself. Then it is wiped with a damp sponge or cloth, a roller charged with printers' ink is passed over it, and the characters reappear more plainly defined than before. To obtain an impression it is now only necessary to lay a sheet of damp paper on the inked stone, and to apply the necessary pressure. After each impression the stone is wiped off with the damp sponge before the inking roller is again applied.

For some time after the discovery of the art impressions were only taken in ink and crayon of one color. Then a new branch of the art, termed chromo-lithography, was introduced, and now facsimilies of paintings in oil, water-color drawings, etc., can be successfully reproduced at prices so cheap that the homes of the humblest are adorned with transcripts of the works of the best artists. The principle of chromo-lithography is necessarily the same as that of the original discovery, the only difference being that each color in the picture to be reproduced requires a separate stone. If there are twenty-five shades of color to be reproduced it is neces-

sary to prepare twenty-five stones. The first thing to be done is to place an outline of the picture on a lithographic stone. This outline by various dots and crosses conveys to the artist just where the impressions of the successive tints are to be placed on the press so that the colors will blend correctly. The gradations of the colors, and their blendings by superposition, require true artists who can thoroughly enter into the spirit of the work. The stone that is to give the blue tints to the picture is prepared with its especial crayon, as are the red, green, yellow, etc. When the stones have all been treated, the printing of the whole series of impressions is proceeded with. The same sheet of paper is laid on each stone in succession as regards the proper order and colors, and with the greatest possible accuracy of register.

The artistic beauty of the modern book or magazine owes much to the art of photography as developed during the latter half of the present Century. The half-tone cuts and photogravures with which even the cheapest periodicals are now replete were unknown less than fifty years ago. The first experiments in photographic printing were conducted unconsciously by Niepce when he was wrestling with the problem of fixing the image of the camera obscura, in the early days of photography; indeed, his first successes in photography were in the reproduction of engravings. In 1852 the engraving process known as the calotype was patented by Fox-Talbot, who has, like Niepce, been introduced to the reader in the chapter dealing with the photographic art. This constituted the first effective printing process in which photography is the primary agent. Since its publication the number of printing processes gradually evolved out of the photographic art are legion. To

treat them exhaustively would require a large volume, and for this reason only a brief general account of those most important to the publishing industry will be given here.

The most popular method of applying photography to the production of printing surfaces is that wherein the portions to be printed stand out like type, receive ink, and are printed in the ordinary manner of letter press. This process owes its origin to Poitevin and Pretch—about the middle of the Century—and has been perfected in late years by the work of Woodbury, Ives, and Meissenbach, the latter's process having been patented as late as 1882. To obtain pictures by this process of photo-engraving the artist makes what is known as a wash drawing, four times as large as the illustration is to be. The drawing then goes to the engraver, who makes what is known as a half-tone cut. The process employed is an interesting one. A glass screen, with diamond-scratched lines, ruled at right angles so closely together that the spaces are hardly distinguishable, is placed one-eighth of an inch in front of the sensitive plate in the photographic camera. Looked through, the effect is much the same as gazing through a fine sieve. These lines reappear in the half-tone engraving when printed. The wash drawing is photographed in the usual way and with the usual sensitized plate, with the screen in the camera between the plate and the picture. This produces the negative of the picture, and in order to have the same position of the object in the engraving as in the original, the film of the negative is treated to one or two coats of collodion, which gives it a consistency to permit of its being removed. This film is transposed to the opposite side of another glass. The new negative is carefully mounted, and used as a medium

for printing on a zinc plate, which has been polished to a high degree, coated with a solution of albumen and gelatine and sensitized with bichromate ammonia. It is then dried and placed in the printing frame, the coated side next to the negative film. Upon being exposed to the light for a sufficient period, the plate is removed from the frame in a dark room and washed under running water, then dried and heated until the picture appears of a dark-brown color. The back of the plate is rubbed with wax while hot to protect it from the etching solution, which eats only where the plate is unprotected—that part which is blank in the unfinished engraving. The plate is allowed to remain in the acid bath for fifteen minutes, or until sufficient depth is obtained. It is then washed, trimmed and mounted for the printer.

The mode of illustration known as photogravure differs from the half-tone engraving in two respects. First, it is printed from an intaglio plate, and second, it is not capable of being used in a type press under any conditions. Where the steam cylinder press can turn out 10,000 perfect half-tone engravings per day, the expert printer cannot produce more than 200 good photogravures. The perfecting of the process, whereby this beautiful style of illustration, is due to Walter B. Woodbury, who took out his first patent for the method in 1866. The process consists in getting an intaglio impression of the image to be copied. The intaglio plate is filled while warm with a hard, stiff ink, which is pressed into every depression. The deepest portions of the mold naturally take the most ink, and represent the darkest shadows, while the shallowest portions represent the more delicate tones. After the high lights of the plate are carefully wiped off by hand, the plate is

run through the press, in connection with the paper, and the latter lifts from the sunken surface of the plate all the ink it has previously received, holding it on the surface of the paper in masses of color differing in depth and consequently in tone, according to the series of graduations from the pure, high light of the clear paper to the rich, velvety black of a solid body of ink spread over the surface of the paper and not pressed into it. The photomechanical process for letter-press printing, which has already been referred to in the chapter dealing with photography, contributes greatly to the cheap production of illustrated books and magazines.

In methods of composition Benjamin Franklin saw no improvement over the infancy of printing. The same monotonous pick, pick, pick, continued through nearly five centuries. In 1875 Ottmar Mergenthaler, a Swiss mechanic and inventor, living in Baltimore, constructed a machine that has been an immeasurable revolutionizing factor in the composing-room. The Linotype is a machine controlled by finger keys, like a typewriter, which creates the type matter as demanded, ready for the press, to be used once and then melted down. Instead of producing single type of the ordinary character, it casts type metal bars or slugs, each line complete in one piece, and having on the upper edge type characters to print a line. These bars are called linotypes and are assembled automatically in a galley side by side, in proper order, so that they constitute a form, answering the same purpose and used in the same manner as the ordinary forms consisting of single types. After being used the linotypes, instead of being distributed at great expense, like type forms, are simply thrown into the melting pot attached to the machine to be recast into new linotypes. The Linotype

is operated by a single attendant sitting at the keyboard. The manipulation of the finger keys by this single operator results in the production, delivery and assemblage of the linotypes in the galley ready for use. In the hands of a skillful operator it will do the work of five men "at the case," or setting type by hand, and will make better wages for him, without half the wear and tear of bone, and blood, and muscle. Within two hours the operator on the machine is able to cast as much new type as the fastest printer can set in seven or eight hours' hard and steady work by the old method. There have been numerous modifications and improvements made upon the original model.

The only formidable rival of the Linotype is the typesetting machine. While the former is a line-casting machine, the latter actually sets the type. One style of the typesetting machine is constructed in the form of a cylinder divided into two parts, having a vertical channel for the reception of the type of exactly the width and depth of the type in use. The upper half of the cylinder is entirely dependent on the lower half, which is stationary, and revolves by a step-by-step movement upon the lower half, in such a manner that the channels in the upper half are superimposed upon those of the lower half, so accurately that, in the very brief pause made by the upper half as it revolves, the type from the upper half are permitted to drop into the channels of the lower half where they belong. The lower cylinder being filled the machine is ready for operation. By the manipulation of the finger-board the type drop, one by one, until there are enough to form a line. At the side of the operator sits the "justifier," who takes, from the long line of type creeping out of the machine, just enough to make one line of the length required, and, as in hand

composition, this is spaced out and mechanically moved out of the machine into a galley attached thereto.

The invention of the process for the manufacture of paper out of wood pulp, described in the chapter on Labor Saving Machinery, has been an important factor in bringing about the cheap production of all kinds of reading matter. At the close of the war publishers used to pay 25 cents per pound for book paper which they can now buy for from 4 to 7 and 8 cents per pound. The very cheap books are made on paper which costs no more than 2 or 3 cents per pound. The commonest kinds of printing paper—those used for newspapers—cost 25 cents a pound thirty years ago, whereas they now only cost 2 or 2½ cents per pound.

Not less remarkable than the machinery and processes introduced into it, has been the development of the modern publishing business. This development has been distinctly along two lines, and represents two extremes. In the first place there was never a time when so many fine books were made. There is absolutely no limit to the sumptuousness of the editions de luxe. The demand for lavish books increases year by year. What makes it more surprising is that while the trade in fine books increases year by year the demand for cheap ones likewise grows. Within recent years an important branch of the business has grown in the publication of books for sale by subscription only. This kind of publication is becoming more and more popular every year, and justly so, for it is the only means whereby a large portion of the reading public are enabled to purchase books, and by the large editions printed enable the undertaking of vast tasks.

The modern newspaper, like the printing press itself, was of long development. Indeed, history claims for the

newspaper a chronology of more than 2,000 years. As a matter of course such virtual newspapers as the ancient Egyptians and Chaldeans published on stone and parchment must be considered as the progenitors of the daily paper as we read it to-day, yet the first really important newspaper, by courtesy so called, was the Acta Diurna of the Romans. Although the news was necessarily all the way from two weeks to three and four years old at the time of its publication, the Diurna was nevertheless quite a gossipy sheet, and as people did not attach much importance to newspapers in those days, the Romans were well content. The Diurna was written—not printed—on parchment. Cicero's oration in defense of Cornelius Sulla was duly chronicled in this newspaper; as was also the fact that on the 4th of the Kalends of April an oak on Mt. Palestine was struck by lightning. The reporters employed on the Diurna and its contemporaries were called actuarii. During the rule of Julius Cæsar copies of the Acta Diurna were posted in the public galleries, and attracted the same heterogeneous crowd of readers as do the modern bulletin boards.

With the advent of the Middle Ages the newspaper idea passed out of existence, and was not resumed until the founding of the Nuremberg Gazette in 1457. Among the most important bits of news which it was the good fortune of this paper to publish to the world was the discovery of Peru. The first Italian newspaper was the Notizie Scritte, issued monthly in Venice, in 1566. This paper was sold for a "gazzeta," a small Italian coin, whence is generally traced the newspaper title "Gazette." The first English newspaper was the English Mercurie, published during the reign of Queen Elizabeth, and is said to have been founded specially

to publish the reports regarding the approach and maneuvers of the Spanish Armada. In 1622 Nathaniel Butter began the publication of the Weekly News, the first regular English newspaper. He also introduced the custom of having newspapers hawked about the streets. The early English newspapers were an unique combination of the incredible, the grotesque and the ridiculous. In the Marine Mercury we read a solemn account of the appearance of a mermaid off the coast of England. The reporter who wrote the article had an extraordinarily vivid imagination, even for a reporter, for he writes that the lady carried a comb in one hand and a mirror in the other.

The contents of the papers were not more remarkable than their names. There were the Mercurius Bellicosus, the Mercurie Pragmatical, and a rival publication, the Anti-Mercurius Pragmaticus; the Parliamentary Kite, the Secret Owl, and a number of others of equally suggestive title. When the original copy was exhausted it was for a long time customary to fill up the gaping columns with appropriate extracts from the Bible, until the editor of the Flying Post hit upon the admirable idea of leaving one-half of his paper blank so that, as he announced editorially, "any gentleman, in sending his copy to family or friends, may dispatch with it his private business." During the reign of Charles the Second English newspapers became such mischief-makers that their number was restricted to twelve. In 1712 a law was enacted placing a tax of half a penny per sheet upon newspapers. Upon the accession of Queen Anne a new era of journalism began. Addison's Spectator and Steele's Tattler, both of which had their inception during this auspicious period, were the foreshadowings of the newspaper of to-day. To Addison belongs the

credit of suggesting the modern newspaper in its chatty trivialities. During Anne's reign the Daily Courant, the first daily paper deserving of the name, was started. The St. James Gazette was established in 1724; the Morning Chronicle in 1769, and the Times in 1788, all three of which have survived until the present time. Although the largest and more prosperous papers in the British Empire, the circulation of none of these exceeded 5,000 copies at the beginning of the present Century. Even so late as 1834 the Times considered itself a marvelously important and prosperous paper with a circulation of 10,000 copies daily.

The first newspaper published in the United States appeared in Boston on September 25, 1690. It was a quaint little sheet, and bore the equally quaint title of "Publick Occurrences Both Foreign and Domestick. Published by Benjamin Harris at the London Coffee House. Printed by Richard Price." The editorial announcement was as follows: "It is designed that the country be furnished once a month (or, if any Glut of Occurrences happen, oftener) with an account of such considerable things as have arrived unto our notice." In 1704 John Campbell, the postmaster of Boston, established the Boston News-Letter, which regaled its readers with extracts from paragraphs in Latin, stating that they would also be favored with literary pabulum in Greek were it not for the lack of the proper type. The people were apparently satisfied with the journalism of the day, and in fact resented any departure from their time-honored traditions. When the Salem Gazette appeared as a bi-weekly there was much indignation over what seemed to the good New Englanders a needless waste of paper and energy. The popular prejudice was expressed thus by a prominent citizen: "It is nonsense to

disturb the people's minds by sending newspapers among them twice a week to take their attention from duties they have to perform."

The beginning of the Nineteenth Century did not see any material improvement in newspapers over those of Addison's time, but as the years went by and as improved machinery and processes for printing and engraving were introduced the modern newspaper gradually came into being. The application of the electric telegraph to the dissemination of intelligence domestic and foreign gave a new significance to journalism, and indeed completely revolutionized that institution. Sunday papers began to appear as the Century neared its first quarter, and in the next twenty-five years the great New York dailies—the World, the Sun, the Tribune and the Times—came into being. In 1843 a very important newspaper event occurred in England. This was the founding of the Economist by James Wilson. This was the first paper to devote itself to the journalism of public economies. When the French traveler, De Tocqueville, visited America in 1835 he was amazed at the number of our newspapers, at the same time deprecating their lack of dignity.

In 1848-49 the Associated Press was formed. This organization became the disseminator of intelligence from all quarters of the globe, and is to-day one of the most important factors in journalism. During the Civil War American newspapers and journalistic methods made great strides, nor have the chariot wheels of progress tarried since that time. Newspapers have been growing better and better and bigger and bigger as the years go by, and in proportion as they have become better and bigger they have likewise grown more cheap and plentiful. The newspaper of to-day is

incomparably the noblest and most useful purpose to which the invention of printing has been turned. It is by far the most glorious of the triumphs which typography, in all probability, is destined to achieve.

The first great step toward facilitating the production of the modern newspaper was made by Colonel Robert Hoe, of New York, in 1840, when the first of the type-revolving presses was built. This invention marked the beginning of an epoch in the history of the printing industry. The Hoe press embodied a new principle, the type being placed on the circumference of a cylinder which rotates about a horizontal axis. At about the same time a type-revolving press was devised by Mr. Applegath for the London Times. In deference to the proprietor of the paper it was called the Walter Press. The only material difference between the English and the American inventions was that in the former the type-holding cylinder revolved on a vertical axis. The capacity of these presses varied according to the number of impression cylinders arranged around the type cylinder, presses being successively made with four, six, eight, and ten impression cylinders, respectively. Among the first of the multiple cylinder presses erected by Robert Hoe was one for the Philadelphia Ledger in 1846, and one for the parisian daily paper, La Patrie, in 1848. The first eight-cylinder press was built for the New York Sun in 1850, and the first ten-cylinder press for the New York Herald in 1857. The modern perfecting press—so called because both sides of the paper are printed in passing through the press—became possible only after the perfecting of the stereotyping process.

Prior to 1860 all promptly issued editions of newspapers were printed from the type forms direct, the type

being locked together on the circumference of the cylinder by mechanical methods. To make stereotype plates with sufficient expedition for newspaper work had not before that time been considered practicable. In 1861 the difficulty was removed by the employment of a steam bed to dry a novel style of papier mache matrix, which could be conveniently used for making stereotyped reproductions of the type pages in the form of plates to fit around the type-bearing cylinders. For this process a number of sheets of tissue paper are pasted together and, while still moist, are pressed into the hollows of the type. A sheet of stout unsized paper, called "plate paper," is then laid on top, and a strong pressure applied. In this condition the paper matrix is dried and hardened by a gentle heat until it is fit to be used for casting the metal. For this purpose the matrix is placed on the internal surface of an iron semi-cylinder, with the face containing the impression of the type inward. The matrix is held in place by clamping screws, a cylindrical iron core occupies the central part of the semi-cylinder, a small space being left between the concave face of the mold and the convex surface of the core. This intervening space is then filled with a molten metal composed of an easily fusible alloy of lead, antimony and other metals. This takes the form of the mold with great accuracy, and when the metal is solidified, which happens very quickly, the core is first lifted out and then the plate in the form of a semi-cylinder, the internal surface of which has exactly the diameter of the external surface of the roller of the machine on which it is to be placed. This semi-cylindrical plate is one-half the length of the roller, and represents one page of the newspaper, so that four such plates are fixed on the circumference of each revolving cylinder. At first it required half an hour to

make a single plate by this process, but now a plate is made in about seven minutes, and a half-dozen duplicates of the same plate can be made in 15 minutes, as the process of casting in no way injures the paper mold. The process of stereotyping is used for all styles of newspaper presses, and frequently for book work of the cheaper grades.

The perfecting of the stereotyping process gave a great impetus to the development of the newspaper as we know it to-day. The type-revolving printing presses, with their capacity of from 10,000 to 20,000 sheets an hour, were the marvel of their time, and did good service during the Civil War from 1861 to 1865. Effective as they were, their supremacy was shortlived, and they are now only a memory. In 1863 the first web perfecting press was erected by Bullock, and the printing industry experienced another great revolution whose ultimate results are the marvelous machines now in use, capable of turning out from 50,000 to 100,000 papers, perfected and folded, in an hour. The Hoe Octuple press of the present day is indeed one of the modern mechanical wonders of the world. This press prints, folds and cuts 96,000 complete eight-page papers per hour, or 1,600 every minute, or 48,000 sixteen-page papers, the size of the page being that of the ordinary newspaper. The press is fourteen feet high and twenty-five feet long. It contains eight impression cylinders, each cylinder having a capacity for eight stereotype plates or pages on its circumference. The paper of double width is fed from four independent rolls, seventy-three inches wide, one side being printed upon as the paper passes over the set of stereotype plates on one cylinder, and the other side being printed upon as it passes over the plates of another cylinder. The paper travels through the cylinders at

the rate of thirty-two and one-half miles per hour, the sheets being automatically cut, pasted, folded and counted out in bundles of twenty-five. Although the work is automatically performed after the press is started it requires the work of ten men and boys to operate the machine and to remove the folded sheets as fast as they are printed.

In 1893 an innovation was introduced into newspaper printing. This was the colored supplement, now so popular in the Sunday editions of the great metropolitan dailies. The idea had long been a fixed one in the minds of newspaper proprietors, but it was impossible to carry it out because up to the date mentioned no machine equal to the quality of work required had been produced. The press which finally met the requirements was that invented by F. Meisel. This press not only prints in four colors in one operation, but prints on both sides, folds, cuts and delivers the sheet free from smudge or offset. The principle involved in the printing of a sheet in three colors and black is that of the solar spectrum, which reduces light to the three primary and the four secondary colors, and by the application of the primary colors, one over the other, succeeds in the production of not only the three colors, but by different surfaces on the printing blocks, obtains the different tones which make color printing acceptable and artistic. The press frame is built in the form of two double arches, between which the different cylinders are placed, there being two cylinders for each color, one to carry the plates and the other on which the printing is done. When the paper is inserted between the first pair of rolls it strikes the yellow, the first color to be printed. This is the first color printed in all processes of printing, and in lithography is called the foundation color. The

plates, which are electrotypes of engravings or the engravings themselves, are made flat, and afterward bent to a size suitable for the cylinder made to receive them. In close proximity to the cylinder is a semi-circular carriage holding the form rollers. These rollers are adjusted in sockets, so that when the carriage is brought into position the inking rollers come in exactly the proper contact with the plates. To supply the rollers with ink the same device common to all presses is used. A fountain of ink is placed in close proximity to the rollers. An iron cylinder revolves slowly in the fountain, presenting a new surface to the fountain roller at every trip which the latter makes to the vibrating distributing roller, which first receives it. The latter is a large roller of steel, which comes in contact with two inking rollers. The ink is well distributed before it reaches the plates by a series of rollers. From the yellow the band of paper passes to the red plates, which are inked in the same way. The result thus far obtained is a sheet of paper clearly printed not only in yellow and red, but there also appear the different tones of orange produced where the red is made to cover the yellow, the depth of tone being dependent upon the relative strength of the yellow and red. The sheet having received its impress from the red cylinder now passes to the blue, from which it emerges colored in all the gorgeous tints of the rainbow. Not only do the yellow, red and blue appear upon the sheet, but all the tints which combinations of those colors naturally produce. After the colors are printed the paper passes to the black rollers. Then it is ready to be printed on the other side. As it leaves the black cylinder the paper is joined by an offset web of manila paper, and together the two webs pass through the last pair of printing cylinders. The

idea of the offset web is to take the surplus ink from the first side, and as it constantly presents a fresh surface the printed paper is freed from smut. This press runs at a marvelous speed considering the complications involved in its work. Seven thousand eight-page sections are printed in an hour, and even a higher speed is possible at the risk, however, of an inferior output.

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